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SYMBIOSIS

A Socio-Physiological Study of Evolution

BY

H. REINHEIMER

Author of "Evolution by Co-operation," "Symbiogenesis" etc.

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Scientific American

"Mr. Reinheimer's book is marked by seriousness of purpose, width of inquiry, and a grasp of several important truths"

Nature

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INTRODUCTION

OURS is a busy age, and it has little patience with long dissertations. I have thought fit, therefore, to preface my remarks by as brief as possible a statement of my case.

The main conclusion which I wish to enforce is that the normal relations between organisms, more particularly those having regard to food, involve, quite indispensably, a stupendous amount of systematic biological reciprocity, so that upon all organisms, be they high or low in the scale of life, there devolve definite duties and obligations, on pain of degeneration or destruction, *viz.*, to contribute in their several ways to the welfare of the organic family as a whole. I consider the normal growth of organic wealth in the shape of powers and capacities as not dissimilar, and not inferior in importance, to that of the normal growth of wealth in human societies. In either case wealth is due to effort, genius, and to the co-operation of all in the utilisation of natural riches.

I regard the totality of organisms as a kind of world-society, the various species and families of plants and animals being the individuals of which this world-society is made up ; and, just as in human societies, the progress and the success or happiness of the individuals depend upon the character of their mutual relations and behaviour, *i.e.*, their conduct. As in human societies, too, such conduct either makes for the good of the whole and the parts or it does not, and so a quasi-moral character belongs to all such "conduct" of individual species. The ways, movements, efforts and aims of organisms are all in this sense "good" or "bad," and there is, therefore, a biological morality throughout, which does not, of course, involve conscious decision or really ethical praise or blame of the individuals concerned. My thesis with regard to evolution is that everything normal and sound in organic evolution is due to biologically righteous, *i.e.*, essentially co-operative, behaviour ; whilst everything abnormal and pathological is due to unrighteous, *i.e.*,

fundamentally predatory behaviour. Although predatory species may apparently, and for a time, live quite well, yet their temporary success is at the expense of permanent survival. This teaching is startling to Biologists, many of whom scoff at the idea of morality or progress in connection with Evolution.

I could myself scarcely have attained to the present outlook but for the aid of special stepping-stones which, quite naturally, led on to higher things. What was it that constituted these stepping-stones? The theses with regard to the Biology of Food previously established by me. These theses briefly are to the effect that (a) perpetual "in-feeding" produces a general predisposition to disease, and (b) that the morbidity so established eventually manifests itself in a tendency to monstrosity. From these conclusions there emerged the corollary that Parasitism not only differs from, but is fundamentally antithetic to Symbiosis, *i.e.*, systematic biological co-operation, and, what is more, that Parasitism is as much abhorred and penalised by Nature as Symbiosis is sanctioned and rewarded. In the sequel I was led on to the broad view that organic evolution itself owes its direction chiefly to a socio-physiological principle, namely, that of "Symbiogenesis," and this view is to be further enforced in the present volume. I have not yet come across a single biological writer who distinguishes fitly between Symbiosis and Parasitism. Yet this distinction is one, I venture to suggest, upon which much, nay very much, in biological interpretation depends. I do not think I am going beyond the facts in stating that, with regard to this distinction, Science has as yet attained no clarity of thought.

Modern Biology is rather seriously handicapped by the lack of an adequate and systematic co-ordination of the many lines of evolution making up sociological development and also by the absence of a comprehensive theory of disease. These deficiencies become the more impressive the more one has had occasion to envisage the wonderful, articulated economy of Nature as exhibited by the phenomena coming under the head of Symbiosis. Small wonder, therefore, that I have felt tempted to expand my exposition of Symbiosis in the attempt to remedy the, to me, most glaring defects of Biology.

I trust that I am not unduly sanguine in hoping for an early acceptance of my socio-physiological views, and that in particular the antithesis between Symbiosis and Parasitism, to

which I attach great importance, may lead to the establishment of a new organon of medicine.

As regards this antithesis, once more, I contend that it is essentially identical with that existing between health and disease. My reasoning is as follows: Symbiosis means partnership—systematic, intimate and laborious. It exemplifies sound Economics. Parasitism, on the other hand, means the denial of such partnership, and the setting up of warfare. It exemplifies unsound Economics. Now when we speak of healthy function—and “function” is a fundamental concept alike of Physiology and of Biology—we mean this: the due performance of “duties” on the part of the units, which “duties,” I submit, are none other than obligations in partnership. Nor does it make any great difference whether these duties are conceived of as physiological rather than biological. In practice these spheres overlap, for Nature knows no watertight compartments as between Physiology, *i.e.*, the functioning of the organism, and Biology, *i.e.*, the inter-relations of organisms and species. In the last analysis, therefore, everything in Physiology or Biology turns upon the performance of duties—duties and partnerships. To live is to be or not to be: in a relation of Symbiosis with the rest of the world. Disturbed “function,” *i.e.*, disease, is, in the main and broadly viewed, a disturbed balance due to a disturbed or perverted partnership. Recent Pathology shows that we may have a kind of “biological” disease superposed upon “physiological” disease. That is to say a disease of the “species” may grow out of a disease of unbalanced, because non-symbiotic individuals; although, as I insist again, the distinction is rather verbal and due to our preference for watertight compartments more than to any real break in the unity of disease. Disease, in my view, is a continuous process—continuous inasmuch as the root-cause, the disturbance of balance, the unbalancing, because non-symbiotic action, or, in other words, the divorce from Symbiosis persists. And inasmuch as the cause persists, disease persists and develops without respecting organs, or organisms, or species; it is “cosmopolitan,” *i.e.*, biological as well as physiological.

What tells most, and is almost the essence of disease, is the loss of resisting power. And this loss, I contend, is universally due to one great cause, namely, action or behaviour that is not according to Symbiosis, *i.e.*, systematic biological co-operation.

I have heard it said that the Physiologist should refer all phenomena of life, as far as possible, to the laws of Physics and Chemistry. I should say that it is more than probable, however, that even this laudable pursuit will ultimately yield nothing more startling than the truth which I have endeavoured to formulate in socio-physiological language. The most important constitutional law of the universe, according to Symbiosis, may be stated in more general terms thus: A body should possess all that is necessary, but no more. Any superfluity acts as an impediment apt to cause disease inasmuch as it militates against usefulness in Symbiosis. And this would also apply in exactly the same way in the physical world. A body needs to be pure and austere constituted lest it lose resistance *pari passu* with (cosmic) usefulness.

Some parts of the book are, I am aware, somewhat technical in treatment; but this was unavoidable in view of my main purpose which was to rescue Symbiosis from "scientific," *i.e.*, specialists' depreciation, and this necessarily required some detailed exposition of my views and the evidence which has led me to adopt them. Further, if my thesis with regard to the extinction of species being ultimately due to a divorce from Symbiosis, was to carry conviction to the professional Biologist, it had to be supported by some detailed palæontological and pathological evidence, which again indispensably entailed the consideration of some technical matters.

CHAPTER I

THE ECONOMY OF NATURE

"Life is that which feels and knows and wills, that for which values exist and which itself exists as a value."—DR. R. M. MACIVER.

BACON, in *Sylva Sylvarum*, says: "There are in Nature certain fountains of justice, whence all civil laws are derived but as streams." This shows a philosophic insight into Nature which is very surprising for the time at which it was written, and which is strictly in line with the conclusions of modern science, a fact which has not hitherto been recognised even by scientific men.

Although mutual aid, sacrifice and altruism have in a general way been recognised as important accessory factors of progress, *the special part played throughout by Symbiosis* and all it involves, has never been demonstrated, nor even, so I venture to assert, approximately apprehended. Those who conceded "co-operation," for the most part held it to be a rather tardy and adventitious auxiliary of "Natural Selection."

It scarcely seems to have occurred to any one so far that a principle so simple as Symbiosis should contain the secret of integrative evolution to a degree which renders it of first-rate importance. True, Herbert Spencer, Geddes and Thomson, Prince Kropotkin, and Henry Drummond have gone so far in adumbrating the economic and quasi-ethical aspects involved in Symbiosis as to concede that without *gratis* benefits to offspring, and "earned" benefits to adults, life could not have continued, nor evolved into higher forms. Yet, so overshadowed has been the whole literature of evolution by the unfortunate metaphor of "the struggle for existence," that the systematic study of the economic and sociological aspects of evolution has been persistently neglected. Whilst "competition" was given the foremost place, the rendering of the long overdue account of what is actually due to co-operation on the one hand and competition on the other, has not even been attempted. Obviously, before we can pronounce as to the relative merits of either factor,

we require to have a due and reliable account of what they have achieved, both singly and in conjunction. The rendering of this account involves the study of what I have called "Bio-Economics," a branch of Biology, the value of which I have set myself the task to get properly recognised. I contend that the closer study of this Bio-Economics—the knowledge of that which makes for true economy in the world of life—can no longer be avoided. Otherwise the biological and sociological outlook will continue to be hazy and ill-defined. We cannot remain content to be ignorant of what really constitutes the distinction between the reciprocal and the non-reciprocal, the useful and the wasteful, *i.e.*, the physiological and the pathological, or, as I might also say, the legitimate and the illegitimate, the moral and the immoral activities.

Darwin believed that a knowledge of variation under Domestication would afford the best and safest clue to the means of modifications. Now, in the light of later biological study, I strongly demur to this, since, in my view, Domestication of the animal is very similar to slavery in the human world and is productive of abnormal and often evil results, as Darwin and others have seen.

Buffon long ago recognised that Domestication produces very grave ill-effects upon animals. He says that "the stigmata of their captivity, the marks of their chains, can be seen upon all those animals which man has enslaved." He speaks of the "ills of slavery" as a main cause of degeneration.

Darwin, in his turn, admits in his *Variations of Animals and Plants under Domestication*, that domestic races of animals and cultivated races of plants often exhibit an *abnormal* character, as compared with natural species *because* "they have been modified not for their own benefit, but for that of man," and he also concedes that the higher variability of domestic productions may perhaps in part be due to excess of food—that is, strictly speaking, a pathological cause. That "fatty degeneration" and precocity are only too frequently induced by Domestication is, of course, well known. Recent research has confirmed the view that the usual methods of Domestication are pregnant with unwholesome results upon the constitution of the organism, that they retard or inhibit its progressive evolution, and it has also brought to light the fact that they are often fraught with undesirable reactions upon man.

Mendelism, again, has shown that Domestication is frequently a process of continuous loss. Everything was there in the wild or independent state; but with Domestication a process of degradation set in and "factor" after "factor" was lost.

Again, in the *Journal of Economic Biology*, June, 1915, Mr. G. Massee points out that the leading idea in dealing with cultivated plants is to intensify or develop to an *abnormal* extent either the flowering, fruiting, or some desirable quality, and in so doing there is a marked tendency to upset the physiological balance of the plant and also to open the door to the spread of disease.

It is, moreover, fairly generally known, as Mr. F. G. Aflalo has said, that the wild sheep is a hundred per cent. cleverer than the domestic animal; and again, the fruiting of the raspberries under cultivation is a much more exhaustive task on the part of the plant than Nature's fruiting of wildlings would be—thus showing losses under Domestication.

Lydekker moreover says that in the wild state the pheasant is content with one wife, but the so-called tame pheasant of our coverts is a polygamist, which is a retrograde step on Herbert Spencer's principle of Sociology as applied to pheasant society. I could easily multiply instances showing the inferiority of Domestication.

There is thus an accumulation of facts showing that what is bad practice in social life is also bad practice when applied to the lower creation. Variation under Domestication should not, therefore, have been relied on as a parallel to Nature's work of *progressive* modification.

On the other hand, Symbiosis is a far better guide to Nature's method, since it is not only free from the blemishes of Domestication, but represents also the source of all wholesome accumulation of what I call physiological capital which is essential to the progress of organic life. Symbiosis teaches that in Nature as in human life the best results are achieved by a system of wholesome—independent though interdependent—labour. The study of this principle provides every justification for Burke's contention, practically identical with Bacon's, however differently expressed, that "there is but one law for all, namely that law which governs all law, the law of our Creator, the law of humanity, justice, equity—the law of nature and of nations."

The lichen, for instance, presents a co-operative association between an alga and a fungus, a union calculated to meet by

mutual effort the economic problem of existence. Systematic economic co-operation in this case of "attached" Symbiosis has led to a high degree of reciprocal adaptation and reciprocal differentiation in the physiology of the organisms concerned. Indeed the physiological reciprocity has here become so intimate that it required years of painstaking research to establish the fact of the compound and dual nature of the lichen.

It is generally a higher fungus which is thus found to be associated with a generally unicellular, sometimes filamentous alga. The special fungi which take part in the association are, with rare exceptions, not found growing separately, whilst the algal forms are constantly found free. The algal forms thus have retained their primitive independence rather more than the fungus, which latter, on the other hand, has stamped its character more prominently upon the compound inasmuch as the reproductive organs of the lichen are of a typically fungal character. The algal cells are never known to form spores whilst forming part of the lichen-thallus, but they may do so when separated from it and growing free. "The fungus," says the *Encyclopædia Britannica*, "clearly takes the upper part in the association."

The fungus, in virtue of its bio-chemical equipment, is better qualified than the alga for the labours of sex. But though the alga, by restraining its own reproductive tendencies, as the *Encyclopædia* says, plays a subordinate part, the part played by the alga is of considerable and far-reaching importance. For the better the associated fungus specialises as regards the reproductive function, more exclusively deputed to it, the better the alga is able to perform its own special photosynthetic duties," *i.e.*, to manufacture essential food and even a surplus of such food, and often various other valuable substances domestically and bio-economically important, which are stored up in the compound organism as capital to facilitate further development.

Lichens are able to live in situations where neither the alga nor fungus could exist alone. The alga is protected by the threads (hyphae) of the fungus, and supplied with water and salts and, possibly, organic nitrogenous substances, and, in turn, it manufactures photosynthetically carbohydrates, the surplus of which it yields to the fungus. This form of relationship is

now known in other groups of plants, though it was first discovered in the lichens. According to the *Encyclopædia Britannica*,

"Lichens are frequently found in the most exposed and arid situations. In the extreme polar regions these plants are practically the only vegetable forms of life and possess the capacity of resisting extremes of warmth, cold and drought without destruction. On a bare rocky surface a fungus would die for want of organic substances, and an alga from drought and want of mineral substances. The lichen, however, is able to grow as the alga supplies organic food material, and the fungus has developed a battery of acids which enable it actually to dissolve the most resistant rocks." (Pioneer work!)

The lichens are characterised by their slow growth, which is associated with great length of life. It is possible, says Dr. O. V. Darbishire, that specimens of such long-lived species of *Lecidea geographica* actually outrival in longevity the oldest trees.

From this we may see that Nature *does* know a method of production and of advance superior to our usual methods of Domestication, which aim at exploitation rather than counter-service. Symbiosis entails the fullest physiological and biological "Give and take." It thus brings about a summation and a gain, rather than a loss, of factors. Symbiosis enriches the protoplasm. Domestication impoverishes it.

Bouglé, a French sociologist, says :

"la mise en commun des forces individuelles engendre une force totale plus grande que leur somme, . . . la combinaison des travaux augmente leur efficacité,"

and this also applies in Nature. Here as there, the more A can rely on B, the more A can give and in turn stimulate B to increasing outputs. Further, the more A and B progress in correlated efficiency, the better will they be able to help C and D, as fellow-members in evolution, causing them, in turn, to increase in efficiency and usefulness. The whole level of life is thus gradually and almost insensibly advanced by every symbiotic increase of power.

What we have shown in detail in the case of the fungus and the alga is paralleled by the relation between insects and plants, except that in the latter we have a more developed, *i.e.*, "un-attached" form of Symbiosis, whilst "attached" Symbiosis is peculiar to the lichen and a few other compound forms. Grant Allen long ago pointed out that the insect has turned the whole surface of the earth into a boundless flower-garden, which supplies it from year to year with pollen or honey, and the plant

in turn gains more assured perpetuation by the baits it offers for the insects' allurements. The conclusion to be drawn is that Symbiosis is responsible for new and improved economic and genetic values. In the course of evolution the range of symbiotic relations has steadily expanded, the partners betaking themselves to wider fields of action though maintaining their essential economic union, *i.e.*, "non-attached" Symbiosis. The joint evolution of plant and animal progressed *au fur et à mesure* as the symbiotic output of mutually valuable substances increased. It is an acknowledged fact that the status of a plant is in accordance to its output of valuable substances, *i.e.*, of biological capital.

An increasing number of biologists look upon the relation of the elements of protoplasm as essentially of the nature of Symbiosis, *i.e.*, as a "partnership" of "life-elements." The principle of partnership, therefore, is very fundamental; and, the more and the better it is applied by the organism, the richer in desirable factors becomes the protoplasm. The wider, *i.e.*, the non-attached forms of Symbiosis, may thus justly be viewed as legitimate extensions of the most fundamental principle of organic life, namely, that of partnership, involving "live and let live."

It is a remarkable fact, connected with plant-animal Symbiosis, that a plant stimulus is required by many animals in reproduction. This I believe to be connected with the fact usually expressed by saying that the "kingdoms" are mutually complementary. In reality, plant and animal are inter-dependent and stand in a relation of Symbiosis to each other. They are co-evolved and, as Darwin long ago apprehended, descended from a common progenitor.

The marvellous genetic purposes to which the bee tribe puts the surplus productions of the plant in "manufacturing" honey, are by no means unique cases of symbiotic adaptation as might be thought; for many other animals also require the vital symbiotic stimulus of plant pabulum in one form or other. In the interesting case, typical of many others, of the plant-animal *Convolvula roscoffensis*, the "attached" Symbiosis is so intimate that, as Prof. F. Keeble has shown, the egg-production ceases as soon as the plant partner (the green cell) is unable to do its share of work through being deprived of light. Moreover, if *Convolvula roscoffensis* is robbed altogether of its ("infecting") green cells,

"life is not worth living, and it dies though surrounded by a plentiful micro-flora of which in happier, infected circumstances it avails itself without stint."

Hence the inference has been drawn that such animals subsist on the food-materials manufactured synthetically by their green or yellow cells.

In these cases other food materials may at times be tempting as a kind of luxury, but for the essential purposes of reproduction only special symbiotic supplies of food are of real avail.

Even at the very lowest rung of the evolutionary ladder we find Symbiosis established. As an instance, I would cite the case of the bacteria. The importance of these micro-organisms and in particular their symbiotic achievements, in virtue of which they have become indispensable even to the highest forms of life, has only quite recently been fully established. Dr. H. F. Osborn, in his essays upon *The Origin and Evolution of Life upon the Earth*, tells us that a bacteria-less earth and a bacteria-less ocean would soon be uninhabitable either for plants or animals, and that in all probability bacteria-like organisms prepared both the earth and the ocean for the further evolution of plants and animals. He instances the *Nitroso Monas* of Europe, presumably a survival from Archezoic time, and provides an interesting description of the industry and of the symbiotic relations of this veritable pioneer of organic civilisation.

For combustion it takes in oxygen directly through the intermediate action of iron, phosphorus, or manganese, each of the single cells being a powerful little chemical laboratory which contains oxidizing catalyzers, the activity of which is accelerated by the presence of iron and manganese. Still in the primordial stage, *Nitroso Monas* lives on ammonium sulphate, taking its energy (food) from the nitrogen of ammonium and forming nitrites. Living with it is the symbiotic bacterium *Nitrobacter*, which takes its energy (food) from the nitrites formed by *Nitroso Monas*, oxidising them into nitrates.

Clearly, without the primal industry of *Nitroso Monas*, the Symbiosis with *Nitrobacter* would be impossible, and without the succession of ever higher but similar forms of life-partnerships, the evolution of the highest forms of life would have been impossible.

The nitrates formed by the symbiotic industry of bacteria are, of course, of immense value, and are practically indispensable

to the Bio-Chemistry of the higher plants and of animals. The higher forms of bacteria also are capable in virtue of Symbiosis of enriching the soil and plant by the fixation of atmospheric nitrogen.

Given therefore a sufficiency of symbiotic endeavour, there will result an ever growing range of fruitful and reliable correlations, and these profitable correlations are as so many external supports, links or tools of life—veritable investments of accumulated marginal or surplus capital. They are sources of further outside services and of various supplementary and complementary supplies, indispensable to progressive life. Just as in the advance of human civilisation, so in Nature the widespread establishment of numerous mutually beneficial “trade” systems with their corresponding momenta for “work,” for “order,” for systematic mutuality—in short the need for preservation of “social” values—acted as so much pressure in the direction of a further general advance. This pressure is implied in the concept of “Symbiogenesis,” by which I mean the direction given to evolution by the long-continued operation of Symbiosis in the production of higher forms of life and in the more complete development of beneficial relations between them.

The terrestrial conditions of life, for instance, are more favourable than aquatic to the advance of Symbiosis, owing to greater security and better opportunities for mutuality and beneficial correlations, in short for “trade.” Upon the land a far greater number of symbiotic momenta could therefore arise and push each other on unceasingly; and the result is that it is upon the land that we find the most developed, the most advanced and the most intelligent animals.

We saw in the case of the lichen that work, accumulation of valuable capital, health, longevity, and generally wholesome influences go together, and we stressed the fact that such happy configuration of “good” factors easily becomes instrumental to vitally important “pioneer”-work; all of which is really of transcendent importance, not only so far as our economic parallel is concerned, but also as a lesson in organic Sociology and in “Evolution” generally. For it is the “pioneer” that matters. The mysterious “common progenitor,” so often invoked by Evolutionists as a kind of *deus ex machinâ* of descent, what is he if not a pioneer—one who by strenuous and mainly symbiotic effort, by wholesome capitalisation, built up essential “endowments”

sufficient to give rise to long successions of *phyla*, orders and genera. It has been found that Symbiosis is, for the most part, ultimately connected with *nutrition*. What is more significant still is this: genuine symbiotic adaptation is everywhere based upon what I have termed "cross-feeding." Be it amongst the symbiotic bacteria, or in the case of the lichen, or in that of the bee and the flower, or in any other case, the significant fact is that we have to do with "cross-feeding," *i.e.*, reliance upon special products of another "kingdom." The animal *Convoluta roscoffensis*, mentioned above, which in virtue of its "garden" of green cells can live and reproduce very comfortably without need of depredation, presents a relation which is not the exception but the norm of Nature. What is exceptional rather in this particular case is that it shows a retrogressive step in Symbiosis, *i.e.*, from the non-attached to the attached form. The inferiority in the Convolutal arrangement is emphasised by its impermanence. This impermanence is clearly due to an insufficiency of the principle of "live and let live" between the partners, a fact to which I shall presently recur. Meanwhile we are warranted to infer that genuine symbiotic adaptation is not compatible with predaceous ways of living, and that the symbiotic relation requires indeed the utmost discrimination as regards food lest the delicate balance of physiological and socio-physiological services that it entails become disturbed. Needless to say, such discrimination is fruitful also in psychological good effects. I would point out in this connection that such mainly cross-feeders as man, the apes and parrots, for instance, rank high in intelligence and status. Had theirs not been a mainly symbiotic history, they would scarcely present, as they do, an almost unbroken tradition of cross-feeding.

Obviously, if the land has provided more favourable conditions than the waters towards the acceleration of progressive evolution, this was in no small measure due to the fact that the land presented conditions more favourable to the "sociological" requirements of Symbiosis, such as are indispensable to physiological perfection. In the case of the lichen, the fungus can be a model partner to the alga only on condition that it exercises forbearance and does not prey upon the alga. It may exchange products; but it must essentially remain a worker and a cross-feeder, *i.e.*, it must draw for sustenance on the soil or on the rocks. The reproductive specialism of the fungus, so useful in the partnership

with the alga, depends upon the fungus' integrity as a worker and cross-feeder. The more the fungus is able, with the aid of the alga, to perfect its chemical specialism, the more this must conduce to an enrichment of the protoplasm. Symbiosis, with its necessarily implied "work," forbearance and restraint, is therefore of immense importance in progressive evolution. And, in general, the better the "sociological" conditions, the more scope there is for physiological elevation.

In the case of *Convolvata* referred to above, Prof. Keeble points out that the relation between the coloured chlorophyll-containing cells and the animal tissues presents the closest parallel to the relation which obtains between the green and the non-green cells of any chlorophyllous plant. What it points to is this: that the relation between the parts of an organism, the so-called physiological economy, is of a similar, if not identical nature with that existing between separate individuals in Symbiosis.

In a strenuous chlorophyllous plant, the more complete and intense the internal Symbiosis, the more assured is the success of the sexual mode of reproduction (as against the mere asexual or seedless method of propagation); and it is to the sexual method more particularly that we owe the most ideal productions of the plant. The asexual method, though common enough, does not represent the highest symbiotic potentiality of the species, but appears rather as an inferior method, necessitated by special conditions of existence. It stands to reason that those of the non-green cells of a strenuous chlorophyllous plant which are to perform the exacting duties of sex, require in turn the utmost co-operation from other cells, tissues and organs. These exacting duties of the sexual cells involve the accomplishment of complete pro-creation with its concomitant demand of a provision of a considerable amount of embryonic and post-embryonic equipment of the new organism. And they involve, moreover, as an indispensable bio-economic concomitant, the simultaneous accumulation of biological exchange capital. For, in order that the race may prosper and the labours of sex be not in vain, provision must be made, over and above embryonic nutrition, for cross-pollination and seed-dispersal. And this contingency requires a permanent symbiotic relation with biological "helpers" or "partners," who in turn require (such are the dictates of "natural Ethics") to be adequately "paid." The plant is called upon to provide "remuneration," or "offerings" adequate

to the needs of its biological "helpers." It is part of the function of sex in plants to provide for these needs.

These needs are indeed calculated to call forth improvements of internal co-operation of the plant. Just as it has been said that the "Eternal Feminine" drags us on, *i.e.*, stimulates towards greater perfection, so symbiotic partnership stimulates progressive developments. It is somewhat in this manner that I believe Symbiogenesis to supplement "Pangensis," and to tend towards the establishment of sociological and physiological gains in support of progressive evolution. Internal and external forms of Symbiosis are thus inter-dependent and supplement each other. The phenomena of Sex, therefore, evidence the importance of the rôle of Symbiosis, *i.e.*, the relation between the sexes is in fact a case of Symbiosis.

We saw how the conspicuous double success of the lichen in achieving fitness and in benefiting the world of life, depended upon the perfection of the symbiotic relation—physiological, sexual and economic—between two organisms of different species.

In the case of the *Convolvuta*, however, the association is of only a transient character. It might be termed seasonal Symbiosis, for the partnership generally ends by the animal partner summarily devouring the green cell partner, the goose which laid the golden eggs, a form of exploitation which precludes the establishment of abiding gains such as are obtained by the internal Symbiosis between the parts of a strenuous plant, by the enduring partnership in the case of the lichen and by the norm of "non-attached" animal-cum-plant Symbiosis in Nature.

Lack or perversion of Symbiosis, physiological or biological, and from whatever cause, inevitably militates against stability, permanence, and effectiveness in the world of life. The "plant-animalism" of *Convolvuta*, because of the one-sidedness of service, approximates to the case of Domestication rather than that of Symbiosis. Domestication we have already found to induce a "misère physiologique." We may explain the "misère" as due to the stifling effects of Domestication upon the "physiological economy," *i.e.*, upon internal Symbiosis, the organism being simultaneously cut off from its true symbiotic bonds in Nature.

As regards Domestication, once more, a creature may be made more conspicuous in appearance, and, in many ways, more

agreeable to our fancies by the usual methods ; yet the result is generally obtained at the expense of evolution. The late Dr. A. Russel Wallace mentioned the fact that the inhabitants of the Amazonian region have a way of inducing obesity in green parrots in order to make them present the most magnificent scarlet and yellow feathers. Instead of feeding them on seeds, their natural food, they feed them on fat. Now feeding on seeds on the part of the bird is in Nature generally associated with the important bio-economic rôle of the bird as seed-disperser. That is to say the normal feeding habit of the parrot is in accordance with a most important symbiotic relation which has been of tremendous consequence in the evolution of plant and animal, and which cannot be lightly infringed. The Amazonian bird fancier obtains his ends at the expense of Symbiosis. But such ends as his are not the ends of Nature. To achieve conspicuous colouration is but poor compensation for the loss of essential capital in other directions, such as is certain to ensue with non-symbiotic feeding.

The case of another parrot, the Australian Kea, shows that a general deterioration of character follows in the wake of a transition from symbiotic to non-symbiotic feeding. This bird, driven into the mountains by man, has taken to rank in-feeding and in fact to murder. It has become a sheep-killer and an "outlaw," and is rapidly undergoing a change for the worse in its once kindly and sociable character. *Convoluta* and changing parrots, therefore, have this in common : the species are not duly, *i.e.*, symbiotically, balanced in Nature.

In his little work on *Degeneration*, Sir E. Ray Lankester long ago stated that :

"Any new set of conditions occurring to an animal which render its food and safety very easily attained, seem to lead as a rule to degeneration."

If food and safety should not be too easily obtained, lest degeneration ensue, it is plain (if moral is what is conducive to progress, and immoral that which retards evolution) that a point of quasi-moral importance is involved in nutrition, and we should not be satisfied to shirk the issue. There must be a principle of Natural Ethics which governs nutrition—a principle by which the instincts of plants and animals are normally guided so as to obviate degeneration and its dire results. I shall revert to this matter in subsequent chapters. Meanwhile we may conclude that if Symbiosis, in virtue of its perfected division of labour, is a means of obtaining a super-adequacy of force from

nutrition; on the other hand organisms can remain adequately symbiotic only on condition that they are sufficiently restrained in their appetites, and that quality and quantity of food are not such as to impede widely useful activities. Failure to live up to its highest symbiotic duty causes the organism to drift from Symbiogenesis into Pathogenesis. And organisms *are* frail. What Burke said of man, namely, that power gradually extirpates from the mind every human and gentle virtue, applies, *mutatis mutandis* to all organisms. The advent of "lucky" circumstances, of "prosperity," is universally apt to cause "back-sliding" from the fine qualities which first led to success:

"Peace makes plentie, plentie makes pride
Pride breeds quarrell, and quarrell brings warre;
Warre brings spoile, and spoile povertie,
Povertie pacience, and pacience peace:
So peace brings warre, and warre brings peace."

The principle of abuse of power thus applies widely.

The plant, as the weaker vessel, is easily and generally made the sufferer. We cannot, therefore, be surprised to find that it has been obliged to evolve thorns, poisons, and other defences in self-protection against depredation. Its chief protection, however, must always consist in the fact of its good biological character, which has the virtue of ranging the most potent biological interests on the side of the plant in its struggle against depredation. A number of plants are poisonous to those animals—veritable "plant-carnivora"—which are wont to be highly destructive *vis-à-vis* to them; whilst the same plants nevertheless may continue to supply wholesome food to other more modest animals. The reaction of the plant against depredation, however, has important and far-reaching consequences: it means the exclusion from the best fare of inconsiderate animals, a fatality which is of great physiological and sociological significance. Failing to obtain the best food, the thriftless animals have to be content with inferior and irregular fare, and often with what they can get anywhere and anyhow. Their "industry" therefore becomes increasingly one of robbery and murder, and their organisation and character change accordingly. Such is the decay of most in-feeders, who develop all manner of morbid and inordinate appetites until finally their diathesis and their plight are such as to cause them to prey upon and even to exterminate each other. Now the course of such developments is not entirely

unfavourable to the plant. For the numbers of "plant-carnivora" are kept down by the inordinate appetites of the rank in-feeders and rank carnivores, which are thus as "executioners" in the service of the plant (by whom they are ultimately maintained). It is not to be denied, therefore, that, owing to the disobedience to the law of Symbiosis, there is a need of "executioners" in the world. It is customary to refer to the respective phenomena by saying that there exist "complex and unexpected checks" amongst organisms "which have to struggle together" (*Evolution*, by Geddes and Thomson, p. 153). A typical example is generally adduced from Darwin's *Origin*, chap. III. It is as follows: "Red clover depends for fertilisation upon the humble-bees, these upon immunity from the attacks of field mice, and thus indirectly upon the number of cats."

Such instances of checks and counter-checks, interesting enough by themselves, have deluded many a reader into facile acceptance of the belief in the blind struggle of organism against organism in Nature, whilst, in my view, they merely illustrate the eternal difference between right and wrong. I should merely say that even cats may be of indirect importance in Symbiosis, namely as "executioners," decimating the "plant-carnivora."

It is of some little interest in this connection to examine Darwin's own account of this case. He says:

"I am tempted to give one more instance showing how plants and animals, remote in the scale of nature, are bound together by a web of complex relations."

(Follow examples of the absolute dependence of some plants upon insect fertilisation, as that of *Lobelia fulgens*, of our orchidaceous plants, of *viola tricolour*, and of clover.) "Humble-bees alone visit red clover, as other bees cannot reach the nectar." (Follows the case of the dependence of clover upon cats.)

"Hence it is quite credible (Darwin concludes), that the presence of a feline animal in large numbers in a district might determine through the intervention first of mice and then of bees, the frequency of certain flowers in that district."

While Darwin's conclusion is correct so far as it goes, I am of opinion that it is nevertheless inadequate because it fails to make us realise the nature of the relations and checks existing between organisms in the web of life. Mere temporary "frequency" of a species in a district tells us little about its real chance of

survival or about its real importance and status in the web of life. The fundamental and abiding fact in the above example is the symbiotic industry of the plant. In this industry the humble-bee shares, not by way of "intervention," as Darwin puts it, but by way of systematic biological partnership. "Interventions" begin with the uncalled for and illegitimate rôle of the mice, whose predatoriness calls upon them the infliction of the hyper-"intervention" of the still more predatory cats. Further, this hyper-"intervention" is not so unconnected with influences coming from Symbiosis as at first sight it looks. For the cats exist only by the good will of man—a symbiotic partner of the plant—whose interest is in so far identical with the plant's as to require the decimation of vermin, if need be by biological "executioners."

Who would deny that man is pre-eminently in need of the industry of the plant; that he is a symbiotic partner of the plant; and that, hence, it is his biological duty to protect the industrious plant as far as possible against its enemies? Is it not, therefore, that the symbiotic plant by its good services unconsciously obtains the most potent, *i.e.*, conscious protection in the world of life? Is it not also that in the place of "unexpected" checks in a vague or blind "struggle for existence," we arrive at the conception of definite checks with strict reference to the bio-economic usefulness of the respective species in the world of life? Professor J. Arthur Thomson states in one of his books that the only correct way of viewing life is to view it whole. "But," he adds, "it is somehow difficult to make good science of the *tout-ensemble*." I believe one reason why we have not yet succeeded in obtaining a good and comprehensive biological science is the wholly arbitrary way in which Biologists regard man as a being apart from nature. No sooner had "Evolution" established man's descent from animal origins than it proceeded to pitchfork him out of Nature—a being quite unique in aims and compelled by them to be in perpetual rebellion against natural law—a view as absurd as that which regards the animal generally as a typically predaceous kind of organism. But man is inseparably linked to the plant-kingdom by eternal laws of organic sociology, and his whole make-up must be understood in the light of that relation. This fact largely accounts for his abhorrence of vermin and even for his occasional alliances with the feline animals—a type of creature

which he has otherwise had good reason to detest. I should say that normally the intervention of neither mice nor cats is necessary for the success of the plant. What is necessary and indispensable is the Symbiosis between red clover and humble-bee. Such Symbiosis primarily determines the numbers of the clover and of the bee. Only in so far as predaceous disturbers of Symbiosis have arisen, is there a need of the intervention of the feline. Necessary though its intervention may be, it is a secondary factor belonging to the utilisation even of partial evil for ultimate purposes of progress. The intervention of the mice is, bio-economically speaking, to quite opposite purposes to that of the bees. That of the mice is noxious and not wanted; that of the bees is essential, fruitful, and evidently desiderated. Unless we draw such qualitative distinctions, we are in danger of arriving at false values, at so preposterous a conception, for instance, as that which looks upon the most thriftless, the robbers and executioners as the mainstays of life. That Darwin was in danger of arriving at some such paradoxical position may be seen from his utterance on the last page of the *Origin*, that "from the war of nature, from famine and death, the most exalted objects which we are capable of conceiving, namely, the production of the higher animals directly follows."

It is not enough to demonstrate the existence of inter-relations and of checks, it is necessary to elucidate the nature of either and this with reference to abiding values. Darwin's remarks that humble-bees alone visit red clover, other bees not being able to reach the nectar, is of some importance in organic sociology. It may be said to illustrate the case of exclusion from want of symbiotic adaptation. What becomes of the excluded animals, we might ask? They must either seek other symbiotic adaptations, or, failing to do so, and failing re-conversion, be content with less and less wholesome adaptations, which means retrogressive evolution and an increasingly precarious existence, albeit such degenerating types may pass through numerous outwardly conspicuous phases of robber existence giving them a fictitious appearance of health and even of viability. Divorce from Symbiosis is fatal. There is no greater error than that which consists in the belief that in Nature the robber and murderer is equally sanctioned with the industrious organism. And let it here be said that a general survey of the feeding practices of the exclusive plant-feeders

amongst animals shows that the animal does not, as a norm, act indiscriminately as a plant-devourer or plant-destroyer ; but it appropriates only certain parts of the plant, the loss of which by no means necessarily leaves the plant the poorer. The plant is the richer in the end for what is legitimately taken from it. \

Fechner suggested that plant and animal should be regarded as "gleichwiegende Faktoren eines lebendigen Wechselverhältnisses" (co-equal factors of a vital reciprocity), and he regarded the whole of human, animal and vegetable kingdoms as indissolubly inter-evolved and inter-linked and forming with the inorganic systems of our globe a "zweckvoll verknüpftes Ganze" (a purposefully inter-linked whole).

This led him on to the idea that with the general progress of things, the blemishes of nature may perhaps gradually diminish or cease to exist altogether.—This is similar to Herbert Spencer's idea concerning the evanescence of evil. Both alluded to some such all-pervading principle of life as Symbiogenesis, which makes for organic and moral values at the same time as it makes for progress and order generally. Spencer declares that "evil perpetually tends to disappear" in virtue of an (un-named) "essential principle of life."

Fechner says in his *Über die Seelenfrage* :

But in the cosmic process disharmonies may last for a millenium in order to be dissolved into harmony in a subsequent one. . . . The dissolution of evil is caused by, and consists in the fact of its being antagonistic to the grand order of things, whereby it stimulates re-actions, which latter augment with the evil and finally surpass it in growth, so that not only is the evil removed, but it is, as it were, transformed into good, and becomes a source of good.—It therefore differs from good only because good is a direct source of furthering the purposes of the grand order of things, whilst evil becomes indirectly a source of good.

It is clear that once we concede a wider "biological citizenship" with its bio-economic and associated bio-moral implications, the old stumbling block of "good and evil" can be largely removed, whilst the wider perspective thus obtained lends itself to a sounder conception of values in many directions where previously uncertainty and doubt prevailed. Once the world-wide web of bio-economic evolution is perceived, it becomes clear that much of the suffering in the world is of a retributive character, and therefore a potential factor for good. Pessimism, on the score of Nature's alleged callousness or cruelty should, therefore, be ruled out of court.

It should now be clearly possible to draw a distinct line between Parasitism and Symbiosis, and this is of the utmost consequence in biological interpretation.

Parasitism is the precise antithesis to Symbiosis. It is, in fact, an extreme form of that "*misère physiologique*," of that diathesis which, as we saw, characterises our domesticated "productions," many of which, though they gain in size, in fatness and in "variability," yet lose capital in a true evolutionary sense.

We shall therefore have to differ from the view expressed in the *Encyclopædia Britannica* that such terms as symbiosis, commensalism and mutualism cannot be sharply marked off from each other, or from true parasitism and must be taken as descriptive terms rather than as definite categories into which each particular association between organisms can be fitted. Symbiosis in that work is actually treated under the head of Parasitism, and writers so advanced even as Geddes and Thomson would seem to look upon Symbiosis as "an instance of a parasitism which is reaching equilibration."* So far from attaching particular importance to Symbiosis, these writers show a predilection to base their theory upon the modifications due to extreme Parasitism.

There is very little doubt, I think, that the self-limitation of naturalists in their consideration of Symbiosis is due to a misunderstanding, or rather a neglect, of fundamental economics. The fact is that as regards Natural Economics we have scarcely got beyond the general concept of the "*modus vivendi*," according to which the strong are credited with so much self-control that they will not devour all the weak so as to prevent the utter destruction of their own food. Apart from the idea of the *modus vivendi*, some writers have also emphasised various other factors as contributive to progressive evolution. The "appetency" of the organism, *i.e.*, endeavour perpetually and imperceptibly working in effect through an incalculable series of generations; the union of diverse sexual elements in fertilisation as a potent source of change; the influence of external factors upon the parturient system; changed "conditions" generally; "use" and "disuse"; the *quasi*-discipline exercised by animate and inanimate nature; the memory factor; all these have been urged. They would seem to require proper

* *Evolution*, pp. 106, 107.

co-ordination and proper unification by being related to some central principle.

Before this desirable end can be achieved, however, we need a valid comprehension of what constitutes true usefulness, *i.e.*, usefulness in the widest evolutionary sense, a valid qualitative standard of measurement. For, *what kind of* "appetency," of "union," "fertilisation," "conditions," "use," and of "discipline" is it that is conducive to definite modification in the direction of progressive evolution?

Some writers seem to have felt instinctively that the answer to such queries must be looked for in Bio-Economics. They have hinted that comparisons with the normal growth of wealth might prove useful. The difficulty here, however, seems to have been that the "Science of Wealth," the "dismal" science, as stated at present, has little commended itself to Biologists. Professors Geddes and Thomson, for example, call it a "pretentious but inchoate would-be-science."

In so far as Economics have hitherto been too arbitrarily or unscrutinisingly drawn upon, there has resulted nothing but defective views and mischief, justifying Samuel Butler's gibes that "as soon as the world began to busy itself with evolution it said good-bye to common-sense and must get on with uncommon sense as best it can;" that "it will take years to get the evolution theory out of the mess in which Mr. Darwin has left it," and justifying also the arraignment of modern Biology by French sociologists on the score of an utter lack of "*jugements de valeur*."

A further result of these shortcomings is that evolution, which, as was well said by Samuel Butler, should affect human affairs at every touch and turn, has become unattractive to the general public. On the whole, it proved true as Henry Drummond remarked, namely, that evolution was given to the modern world out of focus, was first seen by it out of focus, and has remained out of focus to the present hour.

It was not unnaturally expected at one time that "Evolution" would enlighten us about "*les volontés de la nature*" and provide us with "*un mètre du progrès, un critère objectif du bien et du mal*."

But the hopes of the world were to be sadly disappointed. Instead of teaching us the ideal goal and the true means of progress of our own species, Evolution has bid fair to poison our

mental and moral outlook with as fatally defective teachings as were ever promulgated by obscurantists or the professors of the "dismal" Science.

Had Symbiosis been properly appreciated by the pioneers of Evolution, a different view would have resulted. But, as Samuel Butler tells us, in speaking of Buffon, the pioneers were too busy with the fact that animals descended with modification at all, to go beyond the development and illustration of this great truth.

The facts concerning Domestication were much the more familiar and also the more conspicuous. They seemed to present tangible and welcome "proofs" of Evolution in the sense at least of mere modification. In the first flush of "Evolution" it did not seem to be of much consequence if Nature's economic character were somewhat blackened by the implication that she had scarcely known better methods than those of the stockyard. Moreover, Physical Science was in the ascendant and Economics with its adjuncts of morals and religion on the descendant. Thus nature was painted red in claw and tooth, and the natural order was proclaimed as such against which it was right that man should rebel. As the force of this argument increased, creeds ascribing benevolence to Nature tended to become discredited. Teachings such as Rousseau's evangel of trust in Nature became submerged. Jean Jacques, indeed, was now looked upon as a mere babbler.

I fully admit that naturalists were not without merit for having revealed to us what startling powers of discipline there are inherent in the natural process. But it should not have been overlooked that where there is a schoolmaster there is also generally a "good mother," and one good mother, as is well known, is worth more than a dozen schoolmasters. The initial error of Naturalists consisted in mistaking the abuse for the norm in Natural Economics, in making "guilty of our disasters the sun, the moon and the stars," thus causing it to appear as though organisms were "villains of necessity, fools by heavenly compulsion;" and the error bred prolifically.

Granted that Nature has her own chapter of Pathology; but though it presents a veritable "corruption-gendered swarm," this is only the reverse of the medal; and *ex abusu non arguitur ad usum*.

In Political Economy it needed all the powers of advocacy

of a Ruskin to obtain at last some degree of recognition of the "moral signs" attached to wealth—the distinction, that is, between wealth and "illth."

No Ruskin of Biology has however yet appeared to sift the grain from the chaff as regards the rights and the wrongs of "organic capital." I venture to think that the verdict of History will be that both Biology and Political Economy failed of their chief object through a neglect of moral signs.

The pioneers of both sciences wished to avoid such shortcomings by proceeding very comprehensively. Those of Political Economy wanted their science to embrace the natural laws which determine the prosperity of nations, their civilisation, wealth, happiness, etc. They were mindful enough of the Baconian statement which I introduced at the beginning of this chapter. They were in quest, in Bacon's language, of "fountains of justice" upon which to found their science. There are indications indeed to show that they were in quest of something cognate to what I have ventured to call "Bio-Economics." But there was little in the then science of Biology to help them, and later schools, *e.g.*, that of "Natural Selection," implicitly or explicitly denied all justice or morality in Nature. Samuel Butler prefers the older pioneers of "Evolution." He speaks of the days before "Natural Selection" had been discharged into the waters of the evolution controversy, like the secretions of a cuttle fish, and he also states that :

"Our modern evolutionists should allow that animals are modified not because they subsequently survive, but because they have done this or that which has led to their modification, and hence to their surviving."

The hour for the unification of Natural and Political Economy had not struck and, hence, the commendable attempts of the pioneers of Political Economy ended in failure. They were told that the range of their definitions was far too wide, too all-inclusive of the other sciences, so that "the best encyclopædia would really be the best treatise on Political Economy."

But, as the course of that science has evidenced, Political Economy could ill afford to be without knowledge of the natural fountains of justice. Having been too scantily informed on these vital matters by Biology, Political Economy failed, in turn, to become the true handmaid of the former. Both departments of knowledge, therefore, remained more or less "anæmic" and became "dismal" and unsatisfactory in all they taught.

Biologists and Economists have little cause to congratulate themselves on their mutual elevation, and it is scarcely a matter for surprise that there is usually not much love lost between the two.

I hope that I have to some extent shown how necessary it is that Natural and Political Economy should nevertheless complement each other. There should be ample scope for a chapter of "Bio-Economics" in connection with the theory of evolution; and this should in turn furnish Political Economy with appropriate data for a more comprehensive treatment of its own essential subject-matter than hitherto possible.

CHAPTER II

THE LAW OF CONCORD IN NATURE

La nature aime les croisements.—E. FOURIER.

IN the previous chapter I have tried to show that there exists so close a parallel between the Economics governing the growth of the organic world and those governing the progress of human civilisation as to justify the concept of "organic civilisation," and the allied biological concept of "duties" in the way of division of labour and of community of life.

In particular I showed a great "civilising" force in Nature springing from, and associated with, Symbiosis, *i.e.*, the phenomenon of systematic biological co-operation. Symbiosis we found to be the source of accumulation of wholesome physiological capital which is essential to the progress of organic life; so much so that we felt justified in drawing the inference—which is here to be further fortified—that in Nature as in human life the best results are achieved by a system of wholesome, independent, though interdependent, labour.

We found that the existence of numerous symbiotic "trade" systems in the world of life acts as so much "pressure" in the direction of a further and general advance. I spoke in this connection of the principle of Symbiogenesis, meaning thereby the direction given to evolution by the long-continued operation of systematic biological reciprocity in the production of higher forms of life and in the more complete development of beneficial relations between them.

The success of Symbiosis was found to be determined by the completeness and efficiency of reciprocal arrangements, of give and take, and by the absence of depredation. It was also emphasised that Symbiosis primarily subserves a *quasi*-economic purpose in the natural world, that such economic association as Symbiosis primarily entails, in course of time, and with growing efficiency, conduces to pronounced physiological results, affecting sex, structure, status and biological correlations. Stress was

also laid upon the fact that the special adaptations characteristic of Symbiosis are for the most part ultimately connected with Nutrition, which seemed to open up new vistas of thought for a consideration of this very matter of Nutrition—hitherto a veritable Cinderella of Science.

I have stated that Symbiosis was primarily economic, and, seeing that the economic problem is as ancient as Life itself, one cannot be surprised to find that it was a major concern of Life to bring Nutrition under early, socio-physiological regularisation.

And this is saying in other words that the principle of organic self-preservation indispensably demanded that the norm of food getting and of metabolism should accord with co-operative bio-economic laws as opposed to indiscriminate or predatory ways of appropriation which by their lawlessness would have continually endangered the very basis of existence.

My thesis is that food is effective and legitimate in an evolutionary sense—that is in the sense of aiding the progress of organic civilisation—precisely in so far as it is obtained by honest toil and put to symbiotic use. In the previous chapter it was pointed out that only “right” use, “right” union, and “right” appetency (endeavour perpetuated and imperceptibly working in effect through an incalculable series of generations) could have produced evolution in the direction of organic civilisation. In the present chapter it is “right feeding” that is to be particularly insisted upon as an essential condition of progress. I would urge that it is with Nutrition as with Fertilisation ; neither in fact subserves merely the multiplication of individuals, mere “re-production” ; but also, and in the result more fundamentally, the exaltation of type.

As the norm of life, every organism in its development must be passed through the unicellular stage. The fusion of two germ-cells does not result simply in the birth of a new individual, but starts that individual with increased *élan vital*, with increased symbiotic supports. The essence of Fertilisation is thus seen to consist in the raising of the level of being through amphimixis (mingling and mutual stimulation of parental qualities), or, in other words, the sexual form of Symbiogenesis. I believe that something similar is purported by Nutrition, which equally involves protoplasmic union with previous “maturation,” previous Symbiosis and subsequent elevation of type, as we shall

see in more detail hereafter. What is obvious in Fertilisation, namely, that there is co-operation and reciprocal differentiation between the partners, *i.e.*, male and female, is, of course, less apparent in Nutrition; but the indisputable and indispensable connection between Nutrition and Symbiosis nevertheless shows that we must look for a similar nexus in that case.

It should be remembered that, as we now find in so many instances, food exerts a controlling or directive influence upon the development of the organism as well as its growth; and modern discoveries of the effects of vitamins are constantly emphasising this fact.

It is almost absurd to expect otherwise than that in a system so profoundly correlated and co-evolved in its parts as that of organic civilisation, the provision of important stimuli, such as food is capable of conveying, is achieved by very definite arrangements, involving definite biological "duties" on the part of the recipients as well as the providers of the food.

It is also reasonable to expect that the effectiveness of food will be found to depend upon the measure of biological co-operation that went towards its elaboration, and this is what I hope to show.

It has recently been found that ordinary organic substances vary considerably in their behaviour according to their origin, whence it is not a far cry to the recognition that food substances vary in effectiveness in accordance with the nexus under which they have been produced. A symbiotic nexus, for instance, gives rise to such vitally useful substances as the vitamins. A non-reciprocal (or perverted symbiotic) nexus, on the other hand, results in the formation of such substances as the alkaloid poisons, which are so appallingly injurious to the would-be aggressor, or anti-reciprocal factor in the nexus.

According to the investigations of Prof. E. J. Reichart, of Pennsylvania, it would appear that over and above species variation, differences due to environment *and* nurture are clearly manifest in the starches, for instance. In other words, substances vary in accordance with the treatment meted out to the producers of the substances.

In the previous chapter it was already demonstrated from the case of the lichen that the organism which is equipped for Symbiosis is thereby enabled to form powerful and widely useful ferments, and that every increment of Symbiosis must mean

an increment of useful "synthetic mechanism." I would, therefore, propound the view that food is capable of transmitting essential and *quasi*-genetic stimulation and, further, that the effectiveness and the true legitimacy of food ultimately depend upon harmonious and reciprocal relations between food supplier and food-recipient, *i.e.*, upon an adequate symbiotic nexus—analogue indeed to that obtaining between the sexes.

Unfortunately the study of Correlation and of Reciprocity in Nature has hitherto been neglected, more so even than that of Nutrition, and it is little surprising therefore, that to many the attempt to draw a distinction between legitimate or illegitimate feeding will appear almost fantastic. With Correlation and Reciprocity left out of the reckoning, there is indeed scarcely an alternative but to assume that whatever an organism has somehow been accustomed to in the way of foods, constitutes its normal and also its "legitimate" food. Such doctrines, of course, are particularly pleasing to those *quibus in solo vivendi causa palato est*, and some would carry their logic so far as to maintain that in the practice of life one may with impunity disregard Symbiosis and inter-relatedness (or, for the matter of that, the sanctity) of life generally.

La recherche de la paternité est interdite—so ran Napoleon's brutal code, and a number of gourmands would apparently like to have it thus: *La recherche de la légalité de la nutrition est interdite*; but it can be abundantly shown that indiscriminate feeding, regardless of Symbiosis, everywhere results in disease, in retrogression, and in nemesis. There are no short cuts to enduring gains in the physiological sphere any more than in the social sphere of life. Here as there it is true, as Bacon said, that the shortest way is commonly the foulest.

Darwin has shown how felonious food-getting on the part of the bee produces a vicious biological circle, whilst it is apt thoroughly to "debauch" the bee itself. The same sequence of cause and effect is universally observable, as I have been at some pains to demonstrate in every one of my books. A plant that fails to draw mineral salts from the earth will not form regular fibrous tissue of any value and must be the poorer in "capital" and in survival-value. Organisms that draw their nourishment in parasitic fashion from others, instead of obtaining it by work, become as degraded as they become dangerous and thus liable to be exterminated by every means in the power

of the community of strenuous organisms. I have found the analogy with sex everywhere helpful to illustrate that there is a norm of healthy and legitimate feeding. The study of sex has shown that certain modes of protoplasmic union, though quite possible for a time, are yet abnormal and, in so far as they would lead to stagnancy, are really "abhorred" by progressive Nature.

For some 150 years it has become apparent that flowers are adapted to be crossed. Darwin's famous aphorism that "Nature abhors perpetual self-fertilisation," sums up the results of his classical experiments on the subject, although it still leaves us in the dark as regards the real cause of this "abhorrence." It is, however, remarkable that Darwin again and again felt driven in some cases to distinguish between "legitimate" and "illegitimate" fertilisations—merely in view, of course, of results. It is also significant that the immediate results in Darwin's experiments frequently seemed to show that self-fertilisation was not prejudicial to size and numbers. It was only after a great number of generations that what I would consider to be a true super-adequacy of force, due to legitimate and progressive, *i.e.*, genuinely co-operative union, such as obtainable with cross-breeding, became apparent. It was the remoter and permanent result, be it remembered, that led Darwin to his classical pronouncement as to the superiority of cross- over self-fertilisation. The subject is of so great an importance that it will be as well to let Darwin himself speak on its history :

There is weighty and abundant evidence (he says in *The Effects of Cross and Self-Fertilisation*) that the flowers of most kinds of plants are constructed so as to be occasionally or habitually cross-fertilised by pollen from another flower, produced either by the same plant, or generally, as we shall hereafter see reason to believe, by a distinct plant. . . . Long before I had attended to the fertilisation of flowers, a remarkable book appeared in 1793 in Germany: *Das Entdeckte Geheimniss der Natur*, by C. K. Sprengel, in which he clearly proved by innumerable observations, how essential a part insects play in the fertilisation of many plants. But he was in advance of his age, and his discoveries were for a long time neglected.

In the introduction of his book (p. 4) Sprengel says, as the sexes are separated in so many flowers, and so many other flowers are dichogamous, "it appears that Nature has not willed that any one flower should be fertilised by its own pollen."

In 1862 (says Darwin), I summed up my observations on Orchids by saying that nature "abhors perpetual self-fertilisation." If the word perpetual had been omitted, the aphorism would have been false.

Darwin also tells us that Andrew Knight (*Philosophical Transactions*, 1799, p. 202) saw the truth much more clearly, for he remarked that "Nature has something more in view than that its own proper males should fecundate each blossom."

My contention is that fertilisation entails but one—though, of course, a most important—form of symbiotic specialisation, and that Nutrition entails another form of such specialisation, and further that "cross-feeding" is superior to "in-feeding" in a similar way, and for the same reason that cross-breeding is superior to in-breeding, namely, that it is more congruous with the requirements of the symbiotic nexus of life.

The law relating to Nutrition may indeed be stated in analogous and in corresponding terms with that stated by Darwin with regard to Fertilisation, viz., "Nature abhors perpetual in-feeding," with the addendum that what "abhorrence" there is in Nature is mainly due to economic discrepancies arising from modes of feeding subversive of Symbiosis. The term "in-feeding," therefore, is used to denominate the indolent appropriation of food manufactured by close relatives in the biological scale and the correlated shirking of the economic duty of production or of mutual service of some kind. The term "cross-feeding," on the other hand, designates the norm of healthy feeding, associated with symbiotic endeavour, and—so far as the animal is concerned—generally with the ingestion of properly matured surplus products of plant life, which represent the food ideally adapted to the requirements of the animal world.

Nature has thus indeed "more in view" than mere breeding and even mere feeding, and her secret, I maintain, was only very partially discovered by Sprengel, Knight, and even by Darwin. According to my own version of the underlying reality, the bio-economic law of Reciprocity, *i.e.*, that of Symbiogenesis, demands that some new factors—or parts of factors—and certainly at least a modicum of legitimate external support—shall be garnered by the partners in their respective spheres of (specialised) action, and, in a befitting way, be brought into the union. The requirements of a growing organic civilisation, moreover, demand, and actually effect, that many and various symbiotic systems with their "symbiotic momenta" shall push each other on unceasingly to their mutual advantage, that the concord once established between one symbiotic system and another shall be adequately maintained. Such being the essential economic realities of life

on our globe, Feeding and Breeding, Nutrition and Fertilisation had in the main to be ordered in accordance with the requirements of the symbiotic nexus ruling in the world of life—that is to say they are far from being mere self-regarding processes. Had Darwin seen the importance of Symbiosis, as it is possible to-day, he would scarcely have allowed himself to be influenced by Hermann Müller's over-emphasis of propagation *per se* to say that his own aphorism (as stated above) was "perhaps rather too strongly expressed."

We shall see hereafter that symbiotic systems leave the world of life permanently the richer for their presence, and, what is more, that they provide the increments of organic capital essential to the arrival of new, more advanced and better equipped, races of plants and animals. We shall find that the plant, for instance, constantly produces essential organic substances in virtue of Symbiosis—a fact which, once thoroughly grasped, will make a vast difference in biological and sociological interpretation. For it reveals the truth that many important functions hitherto regarded as predominantly self-regarding, are in effect pre-eminently "other-regarding" in character. Strenuous organisms, so long as they have not lost the seeds of the "virtues" engendered in them by the normal course of Nature, affect each other much as do the components of a Parallelogram of Forces: they tend to produce a resultant equal to their combined value, and, what is more,—theirs being a case of living Dynamics, *i.e.*, Bio-Dynamics—this resultant grows cumulatively in force and tends more strongly every day to favour the dominance of Symbiosis, *i.e.*, to uphold the law of Concord, on our globe.

It has been said that Nature is careful of the species, but regardless of the individual. I should say that the method of progressive evolution is to foster a symbiotic resultant rather than to favour particular individuals or species in that merely expedient way, for instance, in which the welfare of every creature is supposed to be looked after by "Natural Selection," acting, according to Darwin, "solely by and for the good of each." To maintain and to increase the dominance of Symbiosis generally, is all that is really wanted to ensure a tolerable security of life concurrently with a certain measure of individual liberty of action. This Bio-dynamic "pressure"- or "resultant"-producing aggregate force of Symbiosis is implied by the term Symbiogenesis. The phrase: The operation of Symbiogenesis

implies that no individual or race exists for itself ; that all have to contribute their share of progress to organic civilisation, that all have to give freely as they also freely receive ; that all have to help in upholding the law of Concord if they are to survive, rather than behave in an anti-symbiotic manner ; and thus there will be scope for mutual elevation rather than for mutual plunder with ensuing stagnancy and retrogression. With sufficient vision we should see that the distribution of real power in the biological polity is similar to the circulation of blood in the healthy body : all correlated parts are reached and remunerated in accordance with their biological dues, and all make their return contribution in various ways so as to merit again in turn more or less remuneration from the general symbiotic fund of the biological polity.

Only in a highly diseased body, the rule of Reciprocity does not hold good, since in this case—for reasons so far considered as mysterious—it appears that the physiological “ control ” is gone, that there is a subversion of the “ ordinary laws ” (whatever they may be) which “ we must assume ” to govern the proportions and proper relations of tissue growth. Tumours, for example, are, contrary to what is the rule with normal structures, imperfectly provided with blood vessels, and, hence, subject to early decay, the resulting cavities or open wounds being exposed to various harmful secondary infections. Cancer, therefore, represents a case of Discord. There is a physiological bankruptcy owing to insufficiency of symbiotic funds and in the ensuing scramble for “ funds ” some cells of the body, the so-called “ cancer-cells,” draw parasitically on the other tissues to the ultimate exhaustion of the body-cells and to their own final doom.

The case is paralleled throughout by the phenomenon of parasitism in Nature. In either case it is generally to be seen that “ rich ” and abundant, yet still incomplete, diet has led up to a slackening and finally a disappearance of the essential symbiotic factors with the identical result of increased liability to retrogressive development, to disease and infection.

Darwin rightly laid stress on the greater health and powers of resistance and the greater constitutional vigour, exhibited by the cross-fertilised plants in his experiments in Fertilisation. The reason is that cross-breeding, like cross-feeding, implies a more extended symbiotic range of life with ampler opportunities for biological exchanges than do in-breeding and in-feeding

respectively. The "cross," in either case, is associated with the more widely useful mode of life. This ensures correspondingly wider symbiotic supports, or greater "returns," which results in dominance, vitality, and resistance to disease. What in the previous chapter we found to be the natural fountain of Justice, thus emerges here again as the true fountain of Health and Power.

Darwin noticed in the case of *Linaria vulgaris* that the crossed plants proved more vigorous than the self-fertilised, and he also tells us that "bees incessantly visit the flowers of this, *i.e.*, the cross-fertilised *Linaria*, and carry pollen from one to the other; and if insects are excluded, the flowers produce extremely few seeds. This, in my view, is typical of the superiority of the symbiotic life over the non-symbiotic—as represented by the in-breeding and in-feeding modes—for, evidently, the former mode involves a widely fruitful intercourse with a happy consummation in correlated progress, arising from extended mutual usefulness, whilst in-breeding and in-feeding modes, with much narrower and more specially self-regarding intercourse, mean relative stagnancy. Another phenomenon that puzzled Darwin is thus also becoming intelligible: the startling amount of expenditure apparently lavished by some organisms towards the attainment of cross-fertilisation. I would view this expenditure as the price paid by the organism for the privilege of due participation in the onward march of organic civilisation and for genuine survival, and particularly so by reason of the fact that the material here in question, which is abundantly produced, *i.e.*, pollen grains, subserves a double, *i.e.*, a domestic and a biological symbiotic purpose.

We can thus understand how it is that longevity is generally related to the standard, *i.e.*, the biological status, of each species in the scale of organisation, as well as to the amount of expenditure in reproduction and in general activity. The secret precisely consists of a widely useful life which shrinks from no sacrifice to merit a permanent place in the forefront of organic civilisation. It consists in a kind of instinctive "wisdom," which proverbially has length of days in her right hand.

The lichen, as was shown in the previous chapter, represents a typical case of a healthy, long-living, resistant and successful organism, clearly distinguished and dominant in virtue of Symbiosis. What is usually overlooked, however, in this

connection, and what is now more specially to be insisted upon is, that the success of the lichen as a symbiotist is essentially connected with cross-feeding.

It is owing to the power of disintegrating by both mechanical and chemical means (says the *Encyclopædia Britannica*), the rocks upon which they are growing, that lichens play such an important part in soil production.

The lichen thus draws its food pre-eminently from the inorganic world, which I claim to be vitally important. It is what I call "cross-feeding" for the plant, and is parallel to the symbiotic draft by the animal on the vegetable world.

The instance of the lichen as a successful "cross-feeder," of course, is not unique; but the same connection, or sequence, holds universally amongst plants, as we shall presently see in greater detail. The case of clover may serve as a first example, illustrating the pronounced good effects of cross-feeding. Says Prof. James Long:

There is nothing in romance or ancient story more thrilling than the fact that by the employment of certain *mineral* fertilisers (cross-feeding!) the clovers and *superior grasses, almost unknown before*, appear and grow with luxuriance; while the inferior grasses and weeds disappear, unable to contend against those species of plants, which—fed by man—(cross-fed!) obtain the mastery of the situation. . . . Clover is a deep-rooted plant and a nitrogen gatherer; while *it revels in particular minerals*. Sometimes one alone, although sometimes two or three are required. Thus, when those foods are supplied, clover responds with its beautiful foliage, its roots *simultaneously piercing the soil to great depths* in search of water, and at the same time appropriating foods, which they find down below and which they bring near the surface *for the benefit of neighbouring shallow-rooted plants*. (Italics mine.)

What strikes one as at least curious is that a case of ordinary legitimate feeding, although indeed combined with pioneer-work in organic civilisation, is to be set down as almost belonging to the sphere of "romance," when it in reality concerns the most universal work-a-day life of plants, on which all organic existence fundamentally depends.

It is now, however, a well established fact that plants generally thrive on mineral food, *i.e.*, on what I call "cross-feeding," and my thesis that Nature prefers "cross-feeding" in the interest of organic civilisation, may be seen to receive considerable corroboration from the following facts and considerations. In a valuable contribution to *The Principles of Crop Production*,

Dr. E. J. Russell refers to a generalisation made by Liebig in 1840, with regard to plant nutrition to the effect that the true function of manure is to provide, *not* organic matter, but *mineral constituents*, which the chemists had ignored.

This discovery of Liebig, according to Dr. Russell, was "a brilliant stroke. It enabled us to reduce the whole art of manuring to an exact science." Before 1840, as this authority tells us :

The practical man knew that farm-yard manure was the great fertiliser ; he also knew that other substances as bones, salt, etc., had, in certain circumstances, considerable fertilising value. The most obvious facts were the large amounts of organic matter in the best manures ; and it is only natural that chemists and physiologists should have connected these and argued that the object of the manure was to furnish organic matter for the plant.

But Liebig's "brilliant stroke" of discovery brushed aside this "obvious connection" and proclaimed that it is the *mineral constituents* that are indispensable and *must be supplied* to the plant, *i.e.*, in my more generalised terminology, that the plant's well-being depends upon "cross-feeding," *i.e.*, on its draft on the inorganic kingdom. True, Liebig had left something out. Thinking that the requirements of a plant could be gauged by the composition of the ash, he overlooked the fact that, "for practical purposes," it was necessary to add nitrogen as well before complete growth could be obtained. For, a complete growth depends upon a complete diet, as a complete heredity depends on a full measure of contribution from the symbiotic environment which, in this instance, is furnished by nitrogen specially elaborated for the plant by friendly bacteria. Dr. Russell tells us that we may take it as established that crops can be grown satisfactorily and indefinitely by supplying proper quantities of suitable compounds of nitrogen, phosphorus and potassium, and he would call this the first principle of Crop production. The first principle of Crop production is, I should claim, an integral part of the greater generalisation that "cross-feeding" is the ideal method of obtaining these essentials of diet for all organisms, and I maintain, that the work of the world is best done on "cross-feeding."

And that such a bio-economic and for that matter widely generalised statement is called for and well justified, is borne out by Dr. Russell's account of the successive steps of

agricultural discovery subsequent to Liebig. For it turned out that the soil presented all the problems of "population," though but of "soil population." In this "soil population" there obtains a wonderful "division of labour," and nothing is left to accident. The higher plant, as has been said, indispensably needs—apart from other *inorganic* substances—nitrates. How are these provided? How also are those organic substances which are often so amply furnished to the plant by the soil after it has been enriched by manure, to be re-converted into inorganic matter so as to constitute the ideal food for the health and the toil of the higher plant? The reconversion, we are told, is neither chemical nor physical. It is "biological." It represents labour performed by that important part of the "soil community" which has long been entirely overlooked, but has recently come into great prominence: the bacteria, the number of which is enormous, running into millions per gram. "How do these organisms live? They must have food; and they must have energy?"

They thrive in part on the spare-capital of the higher plant population with whom they stand in a symbiotic exchange relation so far as their food and well-being are concerned. Nor is the soil an inert medium, but it plays a great part in the business of crop-production. The recognition that the plant is a living thing and that the type of soil is an important factor in crop production, Dr. Russell tells us, has restored perspective and broadened our conception of the factors necessary for plant growth.

It has several times happened in the history of agricultural chemistry (says Dr. Russell) that the new illuminating idea wanted to revivify the subject in a stagnant period has come in from some outside technical problem that had to be solved.

So it was here. The growth of the towns and of stricter ideas on *public health* had brought into prominence the need for better sewage purification, and it was imperative that the problem should be dealt with somehow or other.

Schloessing and Müntz found that *satisfactory purification* involved *the conversion of ammonia into nitrate*, and by a brilliant investigation they found that this process was neither chemical nor physical, but *biological*. Their work was extended to the soil with remarkable results. It was seen that the soil was not a mere inert mass, but that it was teeming with life and pulsating with change. What I would specially urge in this connection

is that the same process which ensures the utmost public health by the purification of sewage also provides the most ideal food, *i.e.*, "cross-food" (nitrates) for the strenuous and symbiotic plant, and further that the "biological" part of the process is mainly made up of the "work" of symbiotic organisms, which are able to perform their indispensable services and thus to form important links in the great bio-economic chain of life precisely in virtue of the symbiotic character of their relations with the strenuous plant.

In other words, the "health" of the soil, the well-being of the soil-"population," and the efficiency of labour on the part of the higher plant, and all these entail, depend upon the maintenance of a definite symbiotic nexus with symbiotic "cross-feeding" as a condition fundamentally indispensable to the maintenance of this nexus. Instead of saying that the important work of converting the ammonia into nitrate is being achieved by a process which is neither chemical nor physical, but biological, I should say that we have here an instance of an essential connection between bio-economic and bio-chemical efficiency of work such as is usually set up by Symbiosis; for the organisms concerned achieve the result by work—chiefly chemical—and they owe their success as much to Symbiosis, as they in turn tend by their work to further Symbiosis. In acquainting us with the history of the soil-"population," Dr. Russell states the following important facts:

A very cursory examination shows that the soil forms only a thin layer, underneath it lies the subsoil, which is wholly different in colour, texture, and especially in its behaviour towards the plants. *Yet there was not always this difference.* When the soil was first laid down it was all like the subsoil, and whenever a new surface becomes exposed, either by landslips, cliff-falls, etc., it is always the subsoil type that appears. The first vegetation has no great supply of plant nutrients, but plants suited to the conditions nevertheless spring up. They take what they can *from the crude soil*, they take carbon dioxide from the air, they synthesise sugars, starches, cellulose, proteins, etc., deriving the necessary energy from sunlight. When the plants die they fall back on the soil and return to it all that they took, and *a good deal more* of new material besides. That introduces a fundamental change. The new material thus added contains stores of energy and food substances suitable for the bacterial population, which forthwith flourishes. Decomposition goes on, nitrates and other substances are produced, and the conditions are made more *favourable for the growth of a new race of plants*. One of the most obvious changes is the formation of nitrates, but other products are formed as well. (*Italics mine.*)

Again it is thus illustrated that all important pioneer-work is done on "cross-feeding," as we found already in the case of the lichen and in that of the clover. The primal plant nutrients are inorganic, although eventually their further elaboration is facilitated by division of labour and exchanges of surpluses in Symbiosis. Strenuous work and Symbiosis provide the original and permanent capital for the purposes of organic civilisation, which can thenceforward proceed to more extended forms of division and specialisation of labour *with resultant exaltation of type*. The evidence shows that pioneer plants leave the soil permanently the richer for their presence—give more than they take—and thus, *and with a subsequent expansion of Symbiosis*, provide the economic and physiological basis of progressive evolution. Such then is the explanation of the arrival of "a new race of plants"—typical of the way in which evolution is achieved by Symbiogenesis. I would only add that the case of animal and plant Symbiosis is quite similar, for the better the animal is supplied by plant surpluses, the more vigorous it gets, the more it can in turn supply the plant with Carbon dioxide and the better it can adapt itself to the needs of progressive evolution generally. As regards the process of nitrate formation by bio-chemical decomposition, Dr. Russell further tells us that the initial products are of little value to the crop or the soil. The *final* (i.e., thoroughly converted) products are invaluable for the plant nutrition. It is of the highest importance that the reaction shall be carried rapidly and smoothly to the nitrate terminus. Where for any reason it is not so completed, the plants cannot be properly fed and "the soil becomes unproductive." When Dr. Russell states that the second broad principle of crop production is "that the bio-chemical decompositions in the soil must proceed smoothly and rapidly," I would say that it is therefore essential that scope must be provided for Symbiosis and cross-feeding to proceed completely and unhindered.

It has long been found that surfeit of any factor otherwise essential to plant growth is harmful. Extra supplies may do harm, either by direct injury or by cutting out another indispensable substance.

We are thus introduced to a "Law of Minimum" as the third principle of Crop production.

Here again I would point out that Symbiosis-cum-cross-

feeding in themselves involve regulative, limiting and restraining factors in so far as every worker or unit is fed in accordance with its contributions, as every substance is supplied in accordance with reciprocal needs, and particularly because a strenuous, working organism has to be restrained in its appetites because of the very fact of work. I would make it a strong point, therefore, that Symbiosis constitutes a safeguard not only of adequate work, but also of normal appetites and, hence, also a safeguard against disease and likewise against prolific reproduction. The symbiotic nexus, as already pointed out, has successfully established itself precisely because of a fundamental and perennial need of regularisation of supply and demand, both of food material and of individuals and species. Those who entirely overlook the indispensable symbiotic nexus in organic civilisation, of course are not unnaturally startled to find that an indiscriminate supply of any one essential substance can have such surprising correlated bad effects as actually exist. Once, however, we grant the need of symbiotic moderation, it is clear that no link in the symbiotic chain of life can be seriously interfered with without other links being thereby thrown out of gear.

The "Law of Minimum," therefore, is nothing more than the "Law of Symbiotic Moderation." This "Law of Minimum," or of "Symbiotic Moderation" is closely akin to another which, as I have elsewhere shown, operates as an application to Biology of Gresham's "Law of Currency," namely, that bad organic "currency" drives out good "currency," much the same as in the life of States bad currency drives out good.

And these laws may indeed be considered as affording further apposite analogy between Sex and Nutrition. The fusion of germ-cells in the process of Fertilisation proceeds in such a manner that after mytosis the germ-cell contains of unclear substances *only that, but all that*, which is necessary to produce a new typical aggregation of hereditary substances. Superfluities are eliminated. The success of that form of sexual co-operation which we call "Fertilisation," would thus seem to depend upon the unimpeded union of essential elements, and the process of Fertilisation, in the last analysis, may be said to purport racial purity quite as much as amphimixis, both being indispensable to true viability and true success.

Physiologists are beginning to see that the process of Digestion *inter alia* purports similar ends, and hence, it is explainable why

a simple and harmoniously balanced dietary is more effective in the end than one consisting of "rich" food and of dainties, replete with artificial stimulations. "*Abbondanza genera fastidio.*"

But fastidiousness must entail a loss of essential symbiotic stimulation with less resistance to disease and with greater strains thrown upon the eliminative system. Hence costly eliminations must ensue in order to maintain a modicum of racial purity, and they cannot but leave baneful effects both upon the digestive and generative systems. There is, that is to say, a nemesis of reproduction following in the wake of nutritional exaggerations, which may now be seen in reality to be a nemesis incumbent upon violations of the biological law of Concord, the *quasi*-moral law of Symbiosis.

It has been found that in the reproduction of a "lawless entity," such as the cancer cell, mytosis is defective. My interpretation is that such abnormality is the result of a pronounced and prolonged "parasitic diathesis"—due in the majority of cases to non-symbiotic feeding—which acts as the very antithesis to the so-called "law of physiological control," which, as already stated, is no other than the law of Symbiosis. When we come to the norm of life, it is everywhere apparent that Nature is frugal, that she is, in Shakespeare's words, "like a thrifty goddess," and that Milton in particular proved himself "skill'd to sing of Time and Eternity," in comparing Nature to a good cateress, who

Means her provision only to the good
That live according to her sober laws,
And holy dictate of spare temperance.

Plant and soil, on Dr. Russell's showing, constantly react upon each other; "each plays an active part, disturbing both the reaction and the distribution of the products." I should say that the plant has its needs and the soil has its needs; and further that the needs of organic civilisation generally must be adequately considered by the agriculturist.

Apart from Symbiosis one might have expected that, in view of its predilection for the end-product, the plant would tend to hasten the essential process of nitrate formation spoken of above. But in reality—the strenuous plant, being a typical symbiotic worker, a genuine agent in the web of life, which does not work for "getting rich" quickly and regardless of other interests—the

plant, Dr. Russell tells us, does *not* accelerate the nitrate formation.

On the contrary, the growing plant appears to retard it, and nitrate is always formed in higher quantities on fallow than on cropped land, even after allowing for what is taken by the crop.

Whatever the exact explanation may be, we may be sure that the fact of Symbiosis necessarily introduces regulative and restraining factors in many directions. It is quite intelligible that the strenuous plant finds a surfeit of nutrients incompatible with its work. It is only the harmful, *i.e.*, the idle and predatory organisms of the soil, that "thrive" in surfeit. These latter, in Dr. Russell's words, given a continued spell of "favourable" conditions (which I take to be conditions favouring surfeit) may even establish "some sort of" superiority. Under the identical conditions the efficiency of the strenuous bacteria falls off, and, therefore, under a resulting double inadequacy of Symbiosis, the plants must suffer. Dr. Russell would roughly divide the soil population into two groups: one favourable to the production of plant food, the other not. This shows that our investigators are driven more and more to make that vital and more generalised and more universal distinction which I have set myself to emphasise, namely, between the symbiotic and the non-symbiotic, the normal and the abnormal, modes of life generally. The way to keep down the noxious, *i.e.*, parasitic population in cultivation consists in sterilisation of the soil.

The useful population is, on the whole, more resistant to adverse circumstances than are the harmful organisms, and, therefore, survives more drastic treatment.

But, if the strenuous organisms are more resistant to adverse circumstances than the parasitic ones, this is precisely because, relying upon honest labour and on the support of Symbiosis, they consequently enjoy better health and stronger constitutions than those whose existence is not so supported. Parasitism, on the other hand, as the economic antithesis to Symbiosis, must make for the physiological antithesis, *i.e.*, for weakness, disease and retrogression, which is amply borne out by results in either case.

To give but one further example of the way in which Parasitism shows itself incompatible with symbiotic support: the Nematode worms, most of which are rank parasites, and which, according to Prof. Arthur J. Thomson, "do not seem to lead on to anything

else," are almost the only animal types without wandering phagocytes—the microscopic symbiotic defenders, discovered by the late Prof. Metchnikoff, which play so great a part in safeguarding the blood of animals against the attacks of injurious microbes.

When Dr. Russell in a subsequent paper* develops the idea of an apparent paradox "that any process fatal to life (but not too fatal) proves ultimately beneficial to fertility, while any process beneficial to life proves ultimately harmful," I would demur. I see no paradox whatsoever in the fact that only conditions favourable to Symbiosis are favourable to life in a real sense, and that on the other hand surfeiting conditions—however acceptable the materials provided would normally be—in so far as they interfere with efficiency of work and of Symbiosis, thus preparing the soil for pathogenic and parasitic rather than strenuous and progressive developments, are really unfavourable to life.

Long frost, drought, heat (says Dr. Russell), benefit the useful makers of plant food, while prolonged warmth, moisture and treatment with organic manures lead to deterioration or to "sickness" as the practical man puts it.

But this is really only saying that in cultivation anything which favours honest labour and Symbiosis *at the expense of Parasitism*, proves in the long run more favourable to life than anything which favours Parasitism at the expense of honest toil and Symbiosis—a truth which is borne out universally and which can lend itself to paradoxes only so long as we fail to draw a clear distinction between the reciprocal and the non-reciprocal, the normal and the abnormal, modes of life.

In my book on *Symbiogenesis* I have stressed the fact, brought to light by recent horticultural investigation at the Woburn Experimental Fruit Farm, that ramming the soil round the tree at the planting has beneficial effects upon growth. It means bringing the roots into intimate contact with the soil, which ensures an ample supply of mineral substances. The salubrious effects of intimate earth-contact in this case, I hold, are due to the fact that it affords to the tree a direct draft upon ideal plant-food, that it entails the most complete "cross-feeding."

The flower must drink the nature of the soil before it can put forth its blossoming.

* *Nature*, Vol. 97, No. 2,433, p. 332.

This view of the matter seems to some extent corroborated by recent experience of Plant-Teratology. Thus it is stated by Mr. W. C. Worsdell, F.L.S., in his work on the subject, that the root of the vascular plant is less prone than any other organ to deviate from the normal form, *i.e.*, it is least predisposed to teratological developments—which are largely pathological.

When we bear in mind that, as I have tried to show throughout, the premier industry of the plant—the industry which, because of its symbiotic significance, is the best safeguard of healthy development—consists in the conversion of inorganic into organic material, it seems doubly remarkable that those parts which are most busily engaged upon such industry, though ever so unobtrusively and even shut away from sun-light, are the most robust in health and the most constant or “normal” in constitution. Little doubt, that the connection with ideal food and ideal work in this instance is a paramount factor in determining the healthiness of the root.

Mr. Worsdell suggests that the comparative stability of the root may be due to its usual

Location in the comparatively uniform environment of the soil, where the factors which induce variation are very much less numerous and varied than they are above ground.

I take it, however, that we have here above all to do with capacity to resist disease, which capacity, as we have seen, cannot be satisfactorily explained on purely mechanical grounds. The soil may present a comparatively uniform “environment,” but surely this “environment” is not germ-proof. If the soil is lacking in factors making for diversity, it also lacks certain factors which usually make for health and normality—such important germicides, for instance, as fresh air and sunlight. The case of the strenuous nitrifying soil bacteria versus the idle or predatory soil organisms supplies strong confirmation of the view that health and resistance everywhere primarily depend upon work and Symbiosis with the necessarily implied cross-feeding.

If it may be said that the resistance to teratological developments on the part of the root is due to the comparatively uniform factors presented by the soil, this view, in my opinion, needs to be supplemented by the further statement that the factors are constant because correlated with symbiotic strenuousness, which *ipso facto* precludes relations with the animate environment that make for morbidity.

According to Mr. F. A. Talbot, writing in *The World's Work*, November, 1918, the farmer's attitude towards "Nitrolim," the artificial fertiliser—a purely inorganic food—is undergoing a complete and welcome change.

What he (the farmer) spurned five years ago he is now embracing with avidity. When Nitrolim is supplied (Mr. Talbot says) the nitrogen is held by the soil, forming as it were a reservoir of supply to the plant, while the free lime, which by the way is given to the farmer who is called upon to pay for the nitrogen content only, by sweetening the soil and improving its texture as well as assisting the bacterial action which is for ever taking place, renders the home for the roots much more congenial.

In other words, it is "cross-food" which supplies the best conditions for work and for Symbiosis, and, hence, for health and true wealth.

Dusty nitrolim (we are also told) has proved more than a match for the most sturdy and aggressive charlock. Sprayed in a dry form it finds the rough surface of the weed's leaves and stalks an excellent refuge, especially when applied while the plague is soddened with dew or other moisture. As it dissolves it exercises a destructive caustic effect, causing the weed to shrivel and die.

But upon the young grain struggling for existence it exercises no deleterious effect; indeed it comes as a welcome stimulant. The capability of a fertiliser to exterminate an enemy while simultaneously stimulating the crop which is menaced is certainly something novel to agriculture, and it is a characteristic which deserves to be noted more widely, if only for the reason that it constitutes the most economical method of eliminating a plant pest which has yet been evolved.

And what is it that now emerges from the foregoing considerations? It is this: The plant is a perpetual worker, a perpetual provider and an ideal capitalist. Having learnt the lessons of strenuous work, having mastered the secrets of various industries and become habituated to the mode of feeding most appropriate to faithful pursuits, it proceeds to employ the populations of the soil, the land and the air, so as to make them co-operate in the great work of organic civilisation. Having obtained such participation to a tolerable extent, it synthetizes, ever more complex organic substances and contrives ever more effective means of arriving at higher values in organic civilisation. By constraining the bacterial and animal populations of our globe to perpetual counter-services, and thus making them partners in the business of organic civilisation, the plant concurrently causes them to participate in the cosmic process of elevating inorganic material to the stage of "organic" life, concerning

which process and its ultimate aim, if any, one can only say with Goethe that Nature alone knows what she wants. This much, however, of eminent importance to our own lives we can gather from the working of this cosmic process, namely, that the more perfect the system of elevating inorganic matter by means of Symbiosis, the higher are the results in organic civilisation and the greater the health, vigour, and dominance of the respective plants and animals. Whilst attending to our own best interests, we may thus at the same time be furthering the remoter ends, if any, of the cosmic process. *Qui sibi amicus est, scito hunc amicum omnibus esse.* So far as concerns the inorganic world's share in Evolution, it seems partly to consist, on the "physical" side, in supporting, in Atlas-fashion, the vast superstructure of the organic world; and, on the "chemical" side, to furnish the latter with appropriate primal stimulations and to guide their application. The earth is like a great store-keeper of energies, and when we see how essential even to the highest forms of organic life is the constant replenishment of their energy in one form or another from the earth's store of primal energies, we are reminded, on the ethical side, of the wonderful inspiration of the Book of Job: "Thou shalt be in league with the stones of the field," and, on the cosmological side, of the mythological figure of Antaeus, the giant of Libya, the son of Poseidon and Gaea, who, when thrown in combat, derived fresh strength from each successive contact with his mother earth, thus symbolising the law of Concord as between earth and man. We are perhaps also reminded of the "Erdgeist" and of Fechner's famous passage, viewing the earth as the grand matrix of all organic life and reality, which so fascinated the late Prof. William James:

We rise upon the earth as wavelets rise upon the ocean. We grow out of her soil as leaves grow from a tree. The wavelets catch the sunbeams separately, the leaves stir when the branches do not move. They realise their own events apart, just as in our own consciousness when anything becomes emphatic, the background fades from our observation. Yet the event works back upon the background as the wavelet works upon the waves, or as the leaf's movements work back upon the sap inside the branch. The whole sea and the whole tree are registers of what has happened and are different for the wave's and the leaf's action having occurred.

There is thus a double concord: between man and the earth,

and between man and the plant ; and the words addressed by Wordsworth to the meek and long-suffering daisy :

Methinks that there abides in thee
Some concord with humanity

contain not only a profound biological and bio-moral truth, but quite possibly also an ampler cosmic truth, relating to the essential interlinking of life, both organic and inorganic, in cosmic evolution.

CHAPTER III

THE ORIGIN OF MORALITY

The religious problem of the present time is determined very largely by the fact that the modern mind, in its attempt to understand life, starts from the platform of Natural Science.—PROF. W. R. BOYCE GIBSON, M.A., D.Sc., in *Hibbert Journal*, October, 1918.

IN the previous chapters it was shown that the progress of the organic world is mainly due to Symbiosis, and what this engenders in values.*

We found that the principle involved in Symbiosis is capable of extension over a wide range though the partners be separate and unconscious of their co-operation. Symbiosis became definable as that system of mutuality (whether between units and units, or males and females, or species and species, or genera and genera, or, finally, and very importantly, between the "kingdoms" on the grand scale of Nature) under which, whilst one part or party devotes itself to one kind of work and yields benefits to others, those others, jointly and severally in their turn performing their special duties, yield benefits to the first in exchange.

In the present chapter, attention is to be more particularly directed to the good moral effects of Symbiosis—which is to be specially vindicated as a source of morality, considered as the gradually established sanction of sound bio-economic relations. The imperative of the moral law is profound and deeply rooted in the order of the universe, as Kant recognised. There is now also an increasing consensus of opinion that consciousness descends to the very lowest forms of organic life.

It is highly probable that the same holds good of morality in the sense at least of reciprocity of conduct. Systematic reciprocity between species or wider groups, or "symbiotic behaviour," involved from an early stage of evolution a kind of morality,

* A good and generalised definition of "value" in this connection, which may be regarded as appertaining also to Biology, is that of Ruskin: "To be valuable," is to "avail towards life." "A truly valuable thing is that which leads to life with its whole strength. In proportion as it does not lead to life, or as its strength is broken, it is less valuable; in proportion as it leads away from life, it is unvaluable or malignant."

a quasi- or Bio-morality ; and it led eventually, by natural momentum, to an ever increasing urge in the direction of increased interdependence and, therefore, of enhanced Bio-morality. This " symbiotic urge " was perhaps adumbrated by Herbert Spencer, when he spoke in 1855, of " that beneficent necessity displayed in the progressive evolution of the correspondence between the organism and its environment."

Let us be clear at the outset about the meaning of this *quasi-* or Bio-morality. I consider that the economic problem was present from the first beginnings of life, and that there were two ways of solving it : first the industrious, as instanced by the symbiotic bacteria and by early symbiotic adaptation generally ; and, secondly, the improvident and predaceous way, as instanced by the devourers and the parasites, *i.e.*, work and theft. The former *régime*, because it allows the welfare of the total organic family to take precedence of the individual gain, I call the good, that is the moral, or bio-moral *régime* ; the latter, because it is one of mere self-regarding expediency, regardless of " higher " or wider interests, I call the bad or immoral *régime*. And I conceive human, *i.e.*, conscious morality to have arisen out of such unconscious Bio-morality, and to be largely dependent for its sanctions, past and present, upon Bio-morality. In my opinion, every stage of life possesses its corresponding degree of mind, consciousness and Bio-morality. I do not claim human consciousness for the bacteria. I only claim that their various ways of solving the economic problem involved conduct which, when good in its tendency or results, I am justified in classing as bio-moral on the ground that it availed towards fuller life.

It is generally conceded that where mind exists, questions of morality begin to arise. To those who deny all mind to the lowest creatures I do not address myself. The leading relatedness in the organic world becoming, from the very dawn of life, one of systematic co-operation, reliance upon this principle became more and more indispensable. This practical indispensability of mutuality in an ever advancing " organic civilisation " found concrete expression in the growth of innumerable faculties for effective mutual stimulation, such as is taking place continually for instance between bacteria and higher plant ; between fungus and alga, forming together the lichen ; and, more generally, between plant and animal on the vast scale of Nature. Symbiosis, therefore, led from early times not only to a multiplicity of

co-adaptations and of correlated faculties, but also to a powerful nexus of sympathy and of bio-economic and bio-moral union, binding together the strenuous world of life.

I strongly insist that morality, at least in the sense of Bio-morality, has as much to do with Biology as morality has to do, on Ruskin's showing, with Political Economy. And I consider that for very important reasons, subsequently to be adduced, a clear conception of the principal data of Bio-morality is of even greater importance than a right answer to the question whether acquired characters are or are not inherited, which answer, according to Spencer, underlies right beliefs, not only in Biology and Psychology, but also in Education, Ethics and Politics. Here as there Spencer's words apply: "A grave responsibility," he says, "rests on biologists in respect of the general question, since wrong answers lead, among other effects, to wrong beliefs, about social affairs, and to disastrous social actions."

But you cannot deal adequately even with "acquisitions" without making due allowance for the concomitant economic and moral, or bio-economic and bio-moral factors; and I believe it can be fully shown that the history of "acquisitions" shows throughout the dependence of progress upon the moral signs attached to them, *i.e.*, whether they represent a plus or a minus of "life" as a result.

Spencer was alive to the great need of ethical principles scientifically derived. He specially admonished us in the Preface to the *Ethics*, that the establishment of rules of conduct on a scientific basis is a pressing need. For, "now that moral injunctions are losing the authority given by their supposed sacred origin, the secularisation of morals is becoming imperative."

Yet, on his own admission, he did not succeed in establishing Evolutionary Ethics as consistently and sufficiently as one could have wished. This I attribute to the lack of knowledge of Bio-Economics. In the absence of this essential chapter of general Biology, we find Spencer having recourse to relative (*i.e.*, empirical) and "absolute" Ethics and even constrained to admit that the doctrine of Evolution had not furnished guidance to the extent he had hoped. Yet, though the doctrine of Evolution, as then formulated, could not help him in "special ways," he thought that it could help at least in general ways by "bringing into view those general truths by which our empirical judgments should be guided."

In their exultation over Spencer's partial failure, some of his critics forget that the doctrine of Evolution was in his time, and still is, in its infancy. When it is said, therefore, that Spencer's disappointment on the score of Evolutionary Ethics was quite inevitable* because in trying to saddle the natural process with Ethics, *i.e.*, conduct determined by conscious will, he was "attempting the impossible," it is overlooked that Spencer nevertheless remained quite hopeful about the eventual solution of the then difficulties. There is nothing in Spencer's writings to justify the temper customary even in scientific quarters which makes men belittle every attempt in the direction of Evolutionary Ethics as a work of supererogation or as belonging to Theology rather than to Science. Some have even gone so far as to deny that there is a Science of Morals at all. Such failures and denials, however, are all alike counsels of despair, as will be evident on a brief examination of the main difficulty.

Without doubt the chief stumbling block has been the obscurity anent "the mutual relations of organisms"—a matter again and again insisted on by Darwin as of the utmost importance, though yet one on which, according to him, "our ignorance is as yet profound." Obviously, as stated above, this matter of relatedness must involve the beginnings of Ethics; and Darwin's pronouncements on the subject ought not to have acted as a deterrent but rather as a spur to further investigation.

Failing the knowledge concerning "mutual relations," the only certainty, according to Darwin's authority, is "Natural Selection," based on "The Struggle for Existence." Had Darwin possessed different facts, such as have since been ascertained, to go upon, and in particular more light respecting "mutual relations," no doubt he would have presented us with a different account of "The Origin of Species." Could it but have been shown that Symbiosis, *i.e.*, useful co-operation, was at work from the very dawn of evolution, that, by augmenting division of labour and by enriching the protoplasm, it directly led to modifications of a permanently useful, *i.e.*, successful order, that it produced the indispensable groundwork for all abiding physiological and psychological gains—what a difference of biological outlook this would have afforded him. Could it but have been shown that very many progressive variations are due not to hazard but to useful work and to the capitalisation of its

* PROF. H. H. SCULLARD, on Christian Ethics, *Hibbert Journal*, January, 1917.

results under the guidance of a persistent and beneficial bio-economic principle, namely, Symbiogenesis, the difference of point of view would have been immense. Nor would the scientific view of morality have incurred the contumely so abundantly and undeservedly heaped upon it since the coming of "Natural Selection." We have already seen in the previous chapters that most of the aforesaid claims in favour of Symbiosis as a useful fundamental and far-reaching form of co-operation can be well substantiated. We found, for instance, that the earliest unicellular creatures, some of the bacteria, already lived in symbiotic relations with manifold and truly astounding success in the way of organic progress. How pertinent were Darwin's words that much had "as yet remained unexplained in the origin of species."

And how much has remained unaccounted for, I would add, in vicarious co-operative sacrifice calculated to support the advance of life! How strangely ungrateful it seems for Man, who has derived immense advantages from the primordial operation of unconscious sympathetic co-operation, impugning Nature as wanting in sympathy and without morality—as non-moral in fact.

We saw that the very inception of the higher races of plants and all that it implied, was directly led up to by Symbiosis. In view of this fundamental fact alone it reads almost like mockery to find Darwin surmising that in Nature variations useful to each being's own welfare may be expected sometimes to occur—*par hasard*. For is not Nature able to produce by accident usefulness to the creature (so ran the argument) if mere man—though by foresight—is able to produce usefulness to himself, as witness the case of Domestication?

Usefulness, however, is a relative and not an absolute term. It cannot be stripped on or off after the fashion of mendelian "characters." Before we can adequately deal with "usefulness" we must know whether it is one that avails to life or towards death. The emergence of viable and really useful variations is not a matter of mere mathematical or kaleidoscopic probability; but is due to the usefulness of the organism's own contributions to the general organic fund of life. Such bio-economic usefulness purchases the wherewithal for a progressive endowment of the germ substance. If the organism on the other hand, indolently plays the losing, *i.e.*, predaceous, game of life, the proto- and germ-plasm become impoverished.

Again, as regards Darwin's term "the struggle for existence," I would point out that the definition leaves a loophole for an interpretation free from the false bias against the "natural process" which the term has unfortunately engendered. The definition, be it remembered, contains the factor of "mutual relations" as an important component—though a mysterious one, a big *X* in the problem.

I use this term (says Darwin in the *Origin*) in a large and metaphorical sense including dependence of one being on another, and including (which is more important) not only the life of the individual, but success in leaving progeny. The mistletoe is dependent on the apple and a few other trees, but can only in a far-fetched sense be said to struggle with these trees, for, if too many of these parasites grow on the same tree, it languishes and dies. In these several senses, which pass into each other, I use for convenience sake the general term of "struggle for existence."

It is not difficult to perceive that all depends again upon "mutual relations." Given, in any particular case, a symbiotic nexus, and Darwin's metaphorical blend means nothing more than progress through peaceful work. Given, on the other hand, a predatory habit, and it means the law of battle.

As regards "success in leaving progeny," I do not think it deserves so high a place as that accorded to it by Darwin. The maintenance of a tolerable degree of evolved Symbiosis in the world of life matters much more than the expansion or even the preservation of a particular species, and this in so far as the welfare of the *tout ensemble* must always take precedence of all other things. Reproduction *per se* is no criterion of success. On the contrary, it is frequently, *i.e.*, where redundant, a symptom of decline. We may consider it as part of the constitution of things that all organisms are, normally, under some restraint as regards multiplication.

Success "in leaving progeny," therefore, is a factor that needs qualification, and we cannot possibly, as consistent qualitative Biologists, assign to it that unqualified importance attributed to it by Darwin.

Reproduction being thus relegated to a second place, it becomes obvious that pride of place in Darwin's formula anent the "Struggle for Existence" must be accorded to the *X* factor, *i.e.*, "mutual relations." And, the significance of *X* being normally "Government and Co-operation," as the "Laws of Life in all things," it follows further that the orthodox meaning

of the term "the Struggle for Existence" must be modified. "Struggle" becomes preponderatingly "peaceful co-operative endeavour."

Let us then, for the sake of clearness, make the necessary discriminations in every case by emphasising everywhere the difference between a life of honest labour and what this involves in health and in capacity of survival, and a life of mere self-regarding expediency and what this, contrariwise, involves in disease, in antagonism, in impoverishment.

Some of Darwin's formulæ, therefore, are susceptible of new or modified interpretations. Indeed, when tested afresh in the light of the facts concerning Symbiosis, they may be said actually to provoke those very interpretations for which I have contended. The "Natural Selection" of "the most favoured races in the Struggle for Existence" becomes the "selection," or rather "survival" of "the most useful," when once it is clearly established that the balance of "favour" in the cosmic scales inclines towards those whose protoplasm is the best endowed; and this is a consequence of widely useful work and its capitalisation in the heritage of the germ. My modification of Darwin's theory thus differs from that of Samuel Butler, who posits an antithesis of "Luck or Cunning" and also from Herbert Spencer's view that "inheritance of acquired characters" is an alternative to crude "Natural Selection" by struggle. I reject, in short, all "non-moral" hypotheses on the ground that they can at best give us only very partial presentments of the truth. Neither "luck," nor "cunning," have, in my opinion, produced the result of Evolution. Useful work, coupled with the principle of "live and let live" has been and is the most potent law of progress. Looking across the ages with a comprehensive glance, I can detect no other agency capable of such achievements as we see. A thesis of this character is obviously sweeping and important enough to deserve further examination. The reader will indeed demand more evidence to show that this equitable principle of "live and let live" has really operated throughout as persistently and consistently as it is here alleged to have done. He will also urge that there are other criteria of morality besides those of usefulness, and he will ask whether they apply as aptly as do those of bio-social usefulness.

The answer in either case is in the affirmative.

For material to go upon we cannot do better than to turn first

to Herbert Spencer, who may justly be regarded as the greatest pioneer of scientific morality. In his search for the origin of altruistic sentiments, Spencer begins with group-morality. He makes no attempt to dig deeper for the roots of morality. According to him,* the root of all the altruistic sentiments is sympathy; and

Sympathy could become dominant only when the mode of life, instead of being one that habitually inflicted direct pain, became one which conferred direct and indirect benefits: the pains inflicted being mainly incidental and indirect.

Here, then, we come across another fundamental criterion of mutual behaviour, that is of moral conduct, *i.e.*, the habitual infliction or non-infliction of pain. And here at once we have an opportunity of showing what far more powerful natural sanctions of morality exist in Nature than those thought of by Spencer and his contemporaries. Nor can we be any longer in doubt as to where in Nature these pre-requisites of "sympathy" are most ideally present. Surely not in the relation of depredation; but certainly in that of Symbiosis, characterised as this is by the strictest law of reciprocity, *i.e.*, of "live and let live," or of biological co-operation in the widest sense.

Spencer shared the common prejudice of his time as regards the inevitableness and compulsoriness of habitual pain at the earlier periods of evolution, before the principle of "live and let live" was introduced by man, as they believed. Speaking of "Animal Ethics," in Vol. II. of the *Ethics*, he says that "Carnage and death by starvation have characterised the evolution of life from the beginning."

It is clear that such views could only have prevailed during a period of neglect of the study of Symbiosis, which has shown the principle of co-operation to have long ante-dated the advent of man. It is, I maintain, a general and fundamental natural principle of which the application by man in society is only a particular phase.

Those views had, however, been accentuated by the false bias created by "Natural Selection" in its crude and exclusive form, which committed them to the emphasis of pain and suffering as the main fountains of happiness, and (inconsistently with the hypothesis of Evolution) to the postulation of a late and

* *Essays*. "Morals and Moral Sentiments."

quasi-miraculous origin of morality with the growth of human or at least the higher animal societies.

It is my chief object in this chapter to emphasise the more hopeful and creditable gospel of evolution as now widely held, in which the law of co-operation is recognised as equally basic in nature with that of competition, and as having an equally ancient and more progressive application, so as to form in the advanced stages of biological and human development the really and increasingly predominant factor.

Even in a relatively recent work on *The New Scientific System of Morality* by Mr. G. Gore, F.R.S., we find the following :

All kinds of animals, men included, torture, kill, and eat each other ; the land, sea, and air are one vast shamble ; kill or be killed, and eat or be eaten are great facts in nature.

Great facts indeed ! But how are we to assess these facts ? And what becomes of our ideas respecting morality and its basis in Nature if we consider these facts as representing the norm of life, when in reality they represent but the degenerative or abnormal phase of life ? The same writer informs us that " as pain and pleasure are states of the nervous system, morality is based upon physiology."

Granted, but is morality to be based on such a physiology as chooses to look upon Symbiosis as the negative pole and upon its opposite, namely, depredation as the positive pole ? The difference matters everything in interpretation, and the reader will thus catch a glimpse of the vast difference of issues at stake between the two forms of activity, *i.e.*, of conduct.

It was thus unfortunately held to be an essential of the new (Darwinian) revelation, that a long protracted, reckless, colossal, and habitual infliction of pain had directly led to the most exalted results in the world. Natural Science seemed to support the view that war, with its tyrannies and brutalities, was the parent of all progress.

Contrary to this view and to Darwin's opinion, the most exalted results of evolution are now seen to be directly due to what was going on in the shape of inconspicuous and thus scarcely noticed sympathetic and reciprocal processes hidden beneath the surface with its show of martial activities, which could only be said at most to have indirectly furthered the cause of progress in spite of their many and obvious effects in the other direction. Spencer himself points out :

The pleasures and pains directly resulting in experience from sympathetic and unsympathetic actions have first to be slowly associated with such actions, and the resulting incentives and deterrents frequently obeyed, before there could arise the perceptions that sympathetic and unsympathetic actions are remotely beneficial or detrimental to the actor; and they had to be obeyed still longer and more generally before there could arise the perceptions that they are socially beneficial or detrimental.

So far then from regarding the respective recognitions of utility as preceding and causing the moral sentiment, he regards the moral sentiments as growing up *pari passu* with the social and anti-social acts, and so as preceding actual intellectual recognitions of utility. This precedence of the moral sentiments is quite in keeping with the view of their origin as here presented, namely, as dating back to primordial economic developments, the economic and bio-economic problem demanding, of organic necessity, primitive forms of morality or quasi-morality. Again I would ask what other principle of organic relations could well have embodied these requisites of gradual, systematic and abiding experience in such ideal perfection as the symbiotic principle? What other principle could have supplied the requisite physiological groundwork for the evolution of sympathy? Where else in the world of life do we find the requisite "obedience" to the laws of protracted association so aptly illustrated as in the integrity of the symbiotic relation—however unconscious the co-operation involved?

I know well that some writers have spoken of the necessity of early service—"involuntary service"—supposed to have gradually led on to voluntary aid. Such service, however, is alleged to have consisted chiefly in sacrifice of life to carnivorous appetites, which are considered "natural" and as justifying the habitual infliction of pain. Prof. Hervey Woodburn Shimer* quite recently put forward such a theory. He contends that service was at first compulsory in the vast majority of plants and animals—the grossest form of such compulsory service consisting in one organism being forced to yield its body for the nourishment of another: "All animals and many vegetable forms are dependent upon the death of other organisms for the prolongation of their own life." "Animals can live only through the death of other animals or plants." How light-heartedly such defamations of Nature are pronounced! Yet, overwhelming evidence goes to show that the rule of life consists in cross-feeding

* *Scientific Monthly*, August, 1916.

and that the cross-feeding animal does *not* need to destroy its food-plants, from which it requires parts only—such as can be spared for the purposes of mutually profitable exchange.

Prof. Shimer takes the usual line of quoting poetry in support of his propositions, as though to range the “gospel of war and damnation” by the side of the Muses. But there is a profound moral chasm there, which no poetry in the world can be found to span, but which on the contrary all great poetry has always deeply bewailed. There is an abyss there which suggests the offering of incense at the altars of Nemesis rather than those of the Muses—Nemesis worship for accumulated biological wrong, which wrong will infallibly sooner or later result in direful events, if not in great catastrophes to the respective species or genera. No poetry can assuage the quakings of the human heart in the committal of wrongs that are “abhorred by Nature.” The fact that the unperverted human conscience shrinks in the face of such wrongs, is proof in itself of the strength of the bio-moral sense and of the categorial imperative of duty which it involves.

Strangely, and inconsistently, Prof. Shimer, who thus defends the predatory life in one of its phases, yet declares that

Parasites are not now, nor ever were in the distant past in evolving lines. Parasites (he says) whether plant, beast or human are degenerate; the individuals become weaker and weaker and finally the life ends in death.

Are we to understand that only excessive depredation causes such a decline? Must we not condemn the principle altogether, seeing more particularly that the story of an inherent and universal compulsoriness of depredation is a pure myth?

If the strength of a parasite is eventually and irrevocably broken and if such a creature becomes malignant during the process, is this not due to the fact that the principle involved, namely, depredation, does not avail towards life?

The best answer is one which refers to the facts. And this brings us back to the subject of the physiological basis of morality. The physiological problem, here, as so often elsewhere, resolves itself into an economic problem. The study of Bio-Economics shows—and further important evidence will presently be adduced to confirm it—that honest work and genuine improvement of organisation are not compatible with rich and over-abundant food and what this implies in more or less predaceous relations. The direful effects of an almost absolute dependence on such food are of course more particularly evidenced by the whole case

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of Parasitism. The dreadful forms of Nemesis to which Parasitism gives rise, are well known ; although the socio-physiological sequence of cause and effect leading up to the fatal results is far from being recognised by orthodox Biologists.

But we need not go to Parasitism, the opposite pole of Symbiosis, in order to demonstrate that predaceous feeding leads to degeneration and ultimate decline. There is plentiful evidence to that effect in the extinction of predaceous species and genera and in the comparatively early senescence of others.

There are, for instance, the one-time terrestrial mammals, the *Cetacea*, such as whales and dolphins, now verging on extinction, which have carnivorously, and, therefore, in my opinion, retrogressively, adopted a marine habitat. A number of zoologists are inclined to look upon the *Cetacea* and their equivalents in degeneracy and monstrosity from the secondary period of geological time—*viz.*, the monstrous marine reptiles, as having reached a stage of senescence and effeteness. It is recognised that they are descended from quadrupeds, which formerly lived on the land, and, therefore, were physiologically superior to their descendants. The arrival of these monsters in a blind alley of evolution, which I would explain on bio-economic grounds—namely, as due to their divorce from Symbiosis—is otherwise regarded as a mystery, and Darwin despairingly exclaims : “ The extinction of species has been involved in the most gratuitous mystery.” “ No one can have marvelled more than I have done at the extinction of species.”

We have as yet to rid our minds of a good deal of prejudice even regarding our terrestrial carnivora. Some may think of the lion as a “ king of animals,” but in reality he is a “ sick man ” and has little chance of survival with the advance of “ organic civilisation.” He stands for “ might is right,” and, therefore, he has to go.

That the principle of depredation is not sanctioned by Nature, is borne out by a number of important facts. It was held at one time that wild animals in nature could not harbour disease. Were they not “ naturally selected ” ? Had they not been passed through “ the sieve of Natural Selection ” ? And was not “ Natural Selection ” as rigid in its operations as, say, gravitation ? What are the facts ? There is a wide zoological distribution of disease, and, further, the more predaceous—and as a

consequence, "kingly" or "majestic"—the organism becomes, the more susceptible it is to infection and disease.

The "huge" and "majestic" sunfish, *Orthogoriscus mola*, for instance, is a veritable hotbed of infection. There are, according to Geddes and Thomson, the tuft of barnacles upon his back, the biting isopods like enormous fleas upon his skin, the trematodes sucking like leeches upon his eyes; and within we find

not only his alimentary canal crammed with worms more than with food, and his liver changed from its natural brown almost into the likeness of a tangle of white worsted, of which each thread is a tape-worm.

We are told that "neither frog nor lizard, serpent nor bird escapes" infection and disease. More and more it is seen that disease has largely a biological origin, *i.e.*, that it is due to some perverted biological relatedness. All of which points to the explanation here adduced that the origin of disease is to be found in a divorce from an erstwhile symbiotic relationship. The parasites infecting the sunfish, or for that matter all parasites, are liable in turn to still more malignant infections, presenting many gruesome phenomena of Hyper-parasitism. Such vicious circles of infection and disease are more frequently met with every day. I have contended these ten years that there is a biological causation of disease and that disease is the most general cause of extinction. I am glad to find this view is borne out by further facts inasmuch as evidence has quite recently been accumulating that infection and disease have been widespread certainly in the early vertebrate periods, with a strong probability that in many cases disease has been the cause of extinction. There has also been a widely felt need among Pathologists for a definition of health in terms of resistance to disease. Here, too, I feel sure the recognition that health pre-eminently depends upon symbiotic support will prove of immense help.

Let us here consider another striking example supporting the important proposition that biological conduct which avails not towards life, renders the organism both weaker and malignant and therefore liable to clashes with the interests of truly viable organisms. Few would have imagined that the case of hay-fever provides an illustration of the biological causation of disease, and, more particularly, of the truth that even comparative improvidence on the part of some organisms contains elements of danger and of disease to others more strenuously inclined.

It is as though Nature had set her face sternly against a widespread "lowering of the tone," against an "infection" of good character by contact with bad, against the application of the well-known principle *Malus malum vult, ut sit sui similis*.

Here we have a case of plants, backward so far as symbiotic relations with the animal world are concerned, whose protoplasm is so poor in values that a union with that of man, for instance, produces violent forms of antagonism and even acute disease. In the absence of active Symbiosis between man and these plants, the seeds of the latter act as poison to the protoplasm of man. There is, it would seem, a clash between genuinely symbiotic momenta upon which health normally depends and momenta of a totally different, *i.e.*, non-reciprocal order.

From a very interesting article on the subject by Dr. W. Scheppegrell, A.M., M.D., in the *Scientific American*, Supp. No. 2119 (12-8-16), we obtain the following data :

The class of plants whose pollen may cause hay-fever are wind-pollinated, that is, the process of fertilisation is effected by the pollen being borne by the wind instead of this being done by contact or by insects. This explains the presence of such pollen in the air. In some cases the pollen is present in enormous quantities, as for instance in the rag-weeds, in which it has been estimated that only one in a hundred million pollen grains is actually used in fertilizing the pistillate flower. The plants that are responsible for hay-fever are practically all common weeds, such as the rag-weeds, cockle bur, yellow dock, etc., which are also a source of expense and labour to the farmer. Their characteristics are as follows : They are wind-pollinated, without attractive colour or fragrance, very numerous, and with abundant pollen. The lack of colour or scent is due to the fact that these plants are wind-pollinated, the qualities mentioned being intended to attract insects for fertilization.

I think it clearly emerges that the culprits are the waywards amongst plants, those that have not been able to strike up a useful symbiotic relation with man or beast. Not being able to render themselves useful, they become impediments and veritable pests. At the same time we see another illustration of the truth that absence of a symbiotic relation renders possible or necessitates enormous though often wasteful and inferior reproduction. We have already inferred that such redundant rates of multiplication are only too likely to be in inverse ratio to biological utility and really connected with pathological conditions. Here we have one pathological terminus more specially brought home to us. We may say that the moderation and restraint incumbent

upon the symbiotic organism are as valuable to life as are the direct benefits bestowed by the symbiotic relation on all participants. In Nature as in human life it is thus true that idleness is the end of chastity and that immoral conduct is the cause of waste and disease to others. Dr. Scheppegegrell is very emphatic that the large majority of the plants whose pollen give rise to hay fever are worthless weeds, "which are alike an expense to the farmer and a menace to health."

We are also told that

The indirect reaction of pollinosis is partly due to the absorption of the protein contents of the pollen, and the toxin formed by the proteolytic action of the cells.

The protein content of the pollen, in other words, gives rise in the patient to an "anaphylactic" condition. The subject of Anaphylaxis and its connections with non-symbiotic methods and ways has been fully dealt with in my book on "*Symbiogenesis*." I think I may fairly refer the reader to that book without enlarging any further on the subject here.

Reverting now to the way in which Symbiosis from the earliest times involved the inception of bio-moral relations, it was, no doubt, the most portentous and the most memorable moment of time when, in the dawn of life, the "genius" of some unicellular creatures hit upon the method of systematic biological co-operation as a means of solving the economic problems confronting them. There was a very long bacterial stage of life, during which epoch bacteria-like organisms prepared both the earth and the ocean for the further evolution of plants and animals. How do such pioneer organisms live? They are simple feeders, deriving their energy and their nutrition directly from inorganic compounds. There is no need for them to resort to depredation. On the contrary. And it is more than questionable whether any degree of depredation would have permitted them to carry on their indispensable pioneer work as efficiently and as successfully as it has been performed by them. These primitive workers relied upon cross-feeding, and, so far from habitually inflicting pain on any sentient creatures, seem to have painfully indeed, but without pain to others, produced an all-essential fund of organic capital for succeeding races of plants and animals. Honest and harmiess toilers these: what grounds have we for alleging that they were not possessed at least of unconscious morality? Do they not fulfil the requirements of morality, as laid down in the

above definitions? It is probable that such types were thus capable of living and flourishing on the lifeless earth even before the advent of continuous sunshine and plant-life.

In previous chapters we have seen how bacterial life provides evidence showing that the evolution of life depended primarily upon wholesome industry, associated with non-predaceous modes of obtaining food. I would emphasise here in particular that such "legitimate" methods of life alone make possible a fruitful Symbiosis. Many of these organisms, moreover, *do not live on organic food in any shape or form*. They refuse, in other words, to live indolently or predaceously at the expense of other creatures—such modes of life not being compatible with genuine Symbiosis. It has been shown that the smallest trace of organic carbon or nitrogen compounds are actually injurious to them. Where is there any infliction of pain upon other sentient creatures habitually resulting, as alleged, from the food requirements of honest toilers? And how can it be said in view of these fundamental and far-reaching facts alone, that the highest results in evolution are due to warfare, famine, death and unscrupulous exploitation of one organism or species by another? Truly, the symbiotic relation represents, in Ruskin's words, the service of Wisdom, the Lady of Health—Madonna della Salute—"differing vastly from the service of Death, the Lord of Waste, and of eternal emptiness." At the lowliest stage of life, where, according to current theories, it would appear as foolish to look for morals or sympathy, where, according to allegations, one should expect to find "struggle" *et preterea nihil*; we find a state of individual and collective integrity so high as to make one feel inclined to supplement the scriptural "Go to the ant, thou sluggard" with the further admonition: "Remember the bacterium."

We find mutual aid based upon mutual trust and this in the absence of any conditions necessitating antagonism. Emphatically we must repudiate the belief that the habitual infliction of pain is according to the normal course of Nature. It is, on the contrary, associated with the abnormal, the degenerative phase of Nature. If those writers who are so sure in their denials of morality in Nature, would but ponder these things and the fact that in their own expositions they can scarcely ever get away from the use of such all-important terms as "obedience," "duty," "good conduct," etc., etc., which do not belong at all to "pure biology," save in so far as it is duly expanded into Bio-Economics.

Many "biological" denials, it is to be feared, are merely the expression of the difficulty adequately to include Economics and Morals in a comprehensive system of "Qualitative Biology." They are counsels of despair, as I have said in the beginning.

In further proof of my contentions, let us turn to Dr. Ch. Mercier, who quite recently vouchsafed the following definition of "function"*: "The duty, office, work or part that is performed by an organ or tissue."

Whence this "duty," we must ask, and what is its significance? And if "function" already implies conscientiousness, how can life maintain itself for long without a conscience? How can there be such a thing as a "pure biology," *i.e.*, alleged to exclude morality, if the most important concept, the alpha and omega of Biology, rests upon "duty"? All health depends on "function," and therefore, by definition, upon "duty"—on "obedience," or "integrity." Evolution itself, we must conclude, inasmuch as it depends upon health, also greatly depends upon morality. In short, no Biology can be complete without the recognition of "the everlasting difference between right and wrong."

It is thus becoming clear that the whole problem of evolution—variation, adaptation and heredity included—turns on this: How best to maintain useful industry and the commensurate degrees of Bio-morality? how best to maintain and to augment fruitful partnerships†; how to perpetuate any new linkage that has proved itself permanently availing in this double economic sense and, hence, towards an ampler life? Work and Symbiosis are indeed the underlying realities, "variations" and "adaptations," the resulting surface phenomena. Bio-morality, as here depicted, thus leaves little to be desired as regards criteria and sanctions. It is our own practice of morality which is so often inconsistent and deficient, our mal-practices leading in turn to wrong beliefs concerning "les volontés de la nature."

Huxley apprehended a great truth only too truly when he stated: "It is not to be forgotten that what we call rational grounds for our beliefs are often extremely irrational attempts to justify our instincts."

Quite recently (24-3-17) a "correspondent" pointed out

* *Science Progress*, October, 1916.

† According to Geddes and Thomson, protoplasm itself is "an unusually fortunate combination of partners, of inventive, organising, administrating, pushing, competitive and other geniuses—yet working in unity."

in the *Times* that the philosophy of Herbert Spencer has gone out of fashion and this for the reason that there "is no hint or promise of religion to be found in it." The critic in short hopes for a salvation of the world from religion—"creative religion." "For what is religion," he says, "but an affirmation of absolute values."

I sympathise to a certain extent with such "creative religion," which would probably have enjoyed the sympathy of Spencer, too, were he alive to-day, in so far at least as it affirms absolute values. It is not to be forgotten, however, that, unfortunately, our religious beliefs are also apt to be coloured by our instincts to the detriment of conduct. Let us have by all means recourse to absolute values. But when super-natural sanction, as so often in the past, does not suffice, let us attempt to supplement religious by natural sanctions. Spencer emphatically held that there was a place for religion in the scheme of things. As he states in Part I., of the "*First Principles*":

Religion, everywhere present as a warp running through the weft of human history, expresses some eternal fact; while Science is an organised body of truths ever growing, and ever being purified from errors. And if both have bases in the reality of things, then between them there must be a fundamental harmony.

Meanwhile our conclusion is that the highest sanction of Nature is bestowed upon that biological relation which, whilst demanding appropriate restraints of the appetites, yet provides the utmost opportunity that each being may develop for the good of all.

CHAPTER IV

EVOLUTIONAL PSYCHOLOGY

Creation, freedom, will—these doubtless are great things ; but we cannot lastingly admire them unless we know their drift. We cannot, I submit, rest satisfied with what differs so little from the haphazard ; joy is no fitting consequent of efforts which are so nearly aimless.—THE RT. HON. ARTHUR JAMES BALFOUR, on *Creative Evolution*, Hibbert, October, 1911.

In the present chapter my object is to show that, in the normal course of Nature, psychical progress is earned by "right" conduct, *i.e.*, by adherence to a "good" and mainly symbiotic pathway of life. Such biologically righteous conduct tends, I believe, in virtue of its wide usefulness in the furtherance of life, to engender new and higher psychic capacities.

As in previous chapters, the guiding idea is that life has always been faced by the economic, *i.e.*, the food problem, and that for several reasons a study of the way in which this, the perennial and central problem, has been attacked and in part solved will provide the most reliable key to the understanding of evolutionary developments.

Spencer, more perhaps than any other evolutionist, was fond of leaning on Economics. There is undoubtedly good cause for the fascination of economic doctrines upon the pioneers of "Evolution." It was not enough to have established "Descent with Modification." It remained to be seen how progress was mainly brought about. And this question, as the pioneers keenly felt on more than one occasion, cannot be satisfactorily answered, unless we know what makes throughout for true economy in the world of life. It is intelligible, therefore, that Economics is again capable of inspiring new lines of thought on the perennial question of evolution.

As regards Psychology, Darwin prognosticated in the *Origin* that in the future it would be securely based on the foundations already well laid by Herbert Spencer, who, in his turn, in "*The Moral Sentiments*," refers us to an Economist, Adam Smith,

as having already made a large step in advance by accounting for the evolution of the moral sentiments, as for instance, when he recognised sympathy as giving rise to the superior controlling emotions of man. It is no coincidence that economic thinkers have contributed so largely to the theory of evolution.

Spencer considered that Adam Smith's theory of the moral sentiments required to be supplemented, for, he says, the natural process by which sympathy becomes developed into a more and more important element of human nature has to be explained; and there has also to be explained the process by which sympathy produces the highest and most complex of the altruistic sentiments—that of justice. Respecting the natural process, Spencer states:

I can here do no more than say that sympathy may be proved, both inductively and deductively, to be the concomitant of gregariousness; the two having all along increased by reciprocal aid.

Having thus emphasised the importance of mutual aid in the evolution of the moral sentiments, Spencer goes so far as to state that the respective gregarious creatures must have "kinds of food and supplies of food that permit association."

We stand here before an all-important convergence of physiological, sociological, and psychological factors, which is well worth investigating and an understanding of which will serve as an earnest of much that follows in succeeding chapters. One might ask, on reading Spencer's passage, whether food is a direct or merely indirect, an active or merely passive, agent in the development of gregariousness and in what this entails in fruitful psychological stimulations. Is it merely that, as Spencer puts it, certain kinds of food, by obviating conditions which render antagonism necessary—although, of course, this means much—passively "permit" higher forms of associations to be formed, or is it perhaps a normal function of certain foods actively and directly to provide useful "influences," sociological and psychological? I think I have made it to some extent clear in previous chapters that much more is involved in food and food-getting than is commonly supposed, and that food in general must be regarded as a very potent determinative and formative agent. It was there also to some extent shown that whether we can have food and food supplies essential to successful association depends upon bio-economic and bio-moral relations as between supplier and supplied. Here it is the more purely psychological aspects

of the subject that interest us. The connection noted by Spencer between sympathy, gregariousness and food, is in reality a very ancient and important one. It existed before "group-morality" and "group-sympathy" inasmuch as the essential factors constituting the connection were already present and co-operating, namely, in Symbiosis, a most successful association of biological partners, which, as I have shown, operated with stimulative, integrative and directive force at the very dawn of life—subsequently contriving to expand its range and to engender new and more potent forms of protoplasm. Symbiosis has been shown to represent the most effective form of mutual service, calculated to generate ever better means of supplying food *pari passu* with increasing bio-chemical perfection. The highly vitalised food in turn engenders increased power and capacities amongst biological complements or "partners" and concomitantly stimulates the growth of Sympathy and of Bio-morality.

Spencer, of course, was not unaware of the great antiquity at least of the roots of Sympathy. In his *Principles of Psychology* he urges that the origin of Sympathy must be traced back to sexual and parental relations. The sexual relation, however, according to him, "can be expected to further the development of Sympathy in a considerable degree only if *it has considerable permanence*" (italics mine).

This qualification of "permanence" is of some special significance. The need of permanence applies indeed in the development of sympathy and of gregariousness quite as much as in the case of Sex and of Symbiosis. We may conclude that there is one and the same underlying reason. For, in order to achieve a wide biological usefulness—the requisite of survival and of success—there has to be a perennial performance of well-regulated services and a permanent and complex system of division of labour; all of which depends in turn upon the gradual establishment of commensurate habits, commensurate adaptations and co-adaptations, involving protracted exercise, protracted endeavour, and long protracted wholesome intimacy. The same factors, indeed, that all along have furthered Symbiosis, also furthered the evolution of Sex and of Sympathy; and these factors are in the main: work, coupled with moderation, restraint with commensurate "sociological" duties—paramount amongst which is the demand for a "live and let live" policy.

Let us recall, as an apt illustration, the case of the lichen. Here we have a relation, primarily economic, namely, a systematic co-operation between organisms of different species, resulting in such mutual stimulation and mutual enhancement as to produce a new and stable relation, and in general such fortification of the protoplasm as to lead to considerable permanence, to considerable degrees of bio-economic and general effectiveness and success of the compound organism.

The manner in which alga and fungus have here compounded their sexual relations following in the wake of economic partnership, and *coupled with non-predaceous ways of feeding*, is symptomatic of the way in which a desirable and lasting intimacy together with genuine evolutionary progress are normally achieved. What it brings out is this: Permanence is contingent upon right sociological and bio-economic conduct. Given this conduct, it is not a long step to the establishment of equitable and lastingly beneficent sexual relations with subsequent acceleration in the development of Sympathy.

The progressive evolution of Sex itself, broadly viewed, provides another illustration of the same truth. The duty of Sex, like that of mind, is, at any rate at the higher stages of life, generally deputed to a special organ which nevertheless depends for its perfect working on the fullest co-operation it can obtain from the other parts of the body. This inner co-operation, or internal Symbiosis, depends, as we have seen, in turn, in an important manner, on the external, *i.e.*, "biological," Symbiosis entertained by the respective species with others. The evolution of Sex may, therefore, be justly viewed as due to the perfection and expansion of Symbiosis. The mammalia, the most developed partners of the plant—to whom they owe an enormous debt—are also the most advanced as regards harmony and perfection of the sexual life and equally as regards mentality and feeling. Here too we have a case of permanence of domestic and biological relations, of mutual forbearance and righteous biological conduct. Man, the most developed mammal, may be said to owe his status largely to the fact that he is essentially a symbiotic cross-feeder and thereby most fitted for permanent reciprocal relations with the higher plants.

More than one Zoologist has expressed wonderment at the astounding number of mammalia that feed more or less exclusively on plant products. And these mainly cross-feeding

groups invariably show greater wealth of species than carnivorous groups. Even amongst Insectivora and Carnivora, there are some species which prefer plant food where they can get it. Orthodox Biology, however, has not yet begun to realise the importance of cross-feeding and of the symbiotic bond which such feeding is calculated to maintain.

Biological status, according to Bio-Economics, depends upon biological service, the highest service producing also the highest form of Sex. Upon the land, for instance, the Cryptogams, amongst plants, with the exception of highly symbiotic lichens, are of comparatively little service to the fauna; and they are also correspondingly backward as regards sex and status.

We may, therefore, conclude that the good psychical effects of gregariousness are due quite as much to the right kind of sociological as of physiological conditions. Gregariousness is the efflorescence as it were, of fruitful socio-physiological relations.

Foremost amongst such relations is the symbiotic relation, which provides the best ground-work for psychological progress. It entails a high degree of mutuality and of division of work together with moderation, which factors ensure viability and plasticity, whilst they are at the same time the most favourable to continuous organic elevation. The predaceous habit, on the other hand, represents the opposite pole—the service of death and of eternal emptiness. The latter, therefore, is incompatible with the principle of Symbiosis and with that of gregariousness.

In previous chapters evidence was provided showing that the biological origin of food, *i.e.*, its “nurture,” is as important in the long run as its chemical composition or “nature;” and we have further seen that symbiotic food is a medium of progressive stimulation *par excellence*. If, as Spencer suggests, certain foods “permit” associations more than others, we may now state with more explicitness that the good effects of food are largely due to the fact of its being normally engendered, regulated and endowed by protracted bio-economic processes. Not only is food thus capable of being “standardised” and fitted to produce maximal harmony amongst inter-related parts, but it is also capable, as we shall presently see good reason to suppose, of conveying direct psychic influences.

We look in vain to any of Spencer's writings for an

adequate recognition of the profound integrative and quasi-genetic rôle played by food in the evolutionary process. To him, food plays a subordinate, passive or static rôle. True, he sees a sequence between the solitary life and habituation to flesh-food. But he looks upon it all from the narrow point of view of individual "profit" accruing to the predatory organism from solitariness—unmindful of the Ruskinian admonition, which I regard as the general law even in matters biological, namely, that "it is only in labour that there can be profit."

Spencer does not see that the bonds of social union must snap asunder from dire "nihilistic" necessity rather than from choice, as soon as in a species life becomes habituated to depredation, which means irregular and inferior food-supplies. "An animal of the predatory kind," he says, "which has prey that can be caught and killed without help, profits by living alone." (*Principles of Psychology*.)

Amongst herbivorous animals, he thinks, gregariousness is general for the reason that the distribution of food is not such as would make isolation decidedly advantageous, whilst certain benefits arise from living together; more especially the benefit that the eyes and ears of all members of a herd are available for detecting danger.

With Spencer, therefore, food at best only permits association in special cases, subordinate to the requirements—the "profits"—in view at the moment. Ignoring Symbiosis, he does not recognise that the right food imparts harmonious, and the food of dishonesty disruptive effects. In his *Principles of Psychology*, the great synthetic philosopher recognises, at any rate in the case of man, that predatory activities have retarded the growth of Sympathy throughout its whole range of evolution. No doubt the suspicion, expressed by him in the same volume, that there is still too much predatoriness in the human race, is only too well justified. As a result of this lingering predatoriness, our sympathies, and likewise our reasoning faculties, are often deleteriously affected.

A brief examination of some of the data of modern Psychology will enable us to understand more fully the important connections between Psychology and Bio-Economics, which require to be elucidated before we can progress very far with Evolutional Psychology. Attention might first be directed to the familiar phenomenon of the concomitance and co-variation of psychic

and physical elements, the close co-operation existing, for instance, between body and mind, which work together for a common purpose, precisely as though they were symbiotic partners and had in the past been jointly under the direction of one and the same principle of evolution. Quite recently a book was reviewed in "*Nature*" on *Man—an adaptive mechanism*, in which its author, Professor G. W. Crile, comes to the following conclusion :

In the web of behaviour, what we call mental and what we call bodily are inextricably interwoven. More than that, the whole bodily life is correlated with a subtlety which can scarcely be exaggerated, verifying St. Paul's remark that the various members of the body work as if they had a common concern for one another.

I would suggest that the most fitting scientific explanation is to say that the parts of the body, physical and mental, work together in internal or domestic Symbiosis—correlated in turn, and in an important manner, with the wider, *i.e.*, biological form of Symbiosis. Professor Crile favours a mechanistic, interpretation of mind—"l'Homme machine." His views however, cannot be said in any way to nullify the bio-economic explanation. What he would leave to the brain as "the initiator of response" and to "the activation of the brain by the inner and outer environment," really covers the most important part of the theory of mind. The brain draws not only mechanical activation but also inspiration from the environment. And it does so in virtue of a happy correspondence, a harmonious relation of the organism with some of the essential factors of the environment. The relation of the brain with the "inner and outer environment" corresponds to the organism's relation of inner and outer Symbiosis. The brain is merely an instrument in facilitating such relations and in capitalising their results. According to the reviewer, Professor Crile :

Gives a very vivid account of the physiological linkage concerned with the transformation of potential into kinetic energy. In this "kinetic system" the brain is the initiator of response, being activated by the environment within or without the body ; acting like a storage battery, it contributes the initial spark and impulse which drives the mechanism.

Although kinetics are, of course, involved, it is yet fairly obvious that theirs is only a subordinate part in the business of life. Organisms, high or low, merely make use of various kinetic systems, such as suit their purposes in life and are possible or commensurate with their economic achievements. The

mechanistic explanation, therefore, is incomplete, and it is evident that this is also the impression left upon the reviewer's mind. He says that he cannot agree with Professor Crile's view that all these wonderful attainments and the "registration of adaptations" have been effected by mechanical formulæ. "We are unable to believe," he continues, "and we have found nothing in this vigorous volume to incline us to transfer the author or ourselves from the category of organism to any other."

"Organism" we thus still remain and as such we are rather above the mere chemical or physical system. We are in fact the controllers or directors of these systems to a considerable extent, as of all bio-chemical wealth—the secret of success in every kind of wealth being—work. In the last analysis, all bio-chemical stimulation is seen to involve bio-economic stimulation. That is to say that the compounding of bio-chemically active substances is essentially due to the operation of Symbiosis, though its hall-marks may not be conspicuous on the surface of things. We noticed in previous chapters how numerous agencies, hitherto believed to be "chemical," are in reality "biological"; and, where their work is beneficial, we have found that it was never a very far cry to Symbiosis.

Organism, then, must be regarded as almost synonymous with worker, just as metabolism is almost synonymous with functional activity. It would be as well if in all future biological dissertations the term "organism" connoted work. Such connotation would be a good beginning towards the abolition of the present indeterminateness of biological concepts.

It is a tenet of Psychology that an object must make a sufficient "appeal" to the attention in order that a "lively" interaction between mind and object may arise, and a mental attachment leading to further developments of mind may ensue.

In other words, a living connection re-calling the interaction of partners in Symbiosis is wanted. The more interaction, the more progress. "Appeal" suggests the existence of some latent Sympathy between object and mind. One might ask: Whence come the possibilities of "lively" interaction and what is their significance? Object and mind evidently are of some importance to each other, and their inter-relation is of importance also to the world at large. If the mental attachment is to be fruitful in permanent good effects, there must be fulfilled the requisite condition of wide biological usefulness, which alone

can provide the necessary support and sanction. How, in the absence of these, could the union resist the corroding influences of temptations to less viable purposes, in fact of degeneration? Resistance to inferior psychological as to inferior physiological influences is a most important matter, and in either case it is connected, I maintain, with the degree of biological sanction that a particular species deserves. It is not difficult to see, that in mental, just as in more purely physiological evolution, there is a perennial need of a steadying and directive principle, operating with persistent reference to the maximal good of life, such as I affirm Symbiogenesis to be. For the mind is proverbially fickle and needs constant restraint and direction from many sources.

Let us take, as an example of "appeal," the case of the attraction exerted by seeds and fruits upon the "minds" of animals. Here we have a case in point of an appeal to the attention with an often recurring "living" interaction between mind and object. Let no one say that I am selecting a case which lends itself more particularly to special pleading. On due analysis, it will be found that all important Psychogenesis resolves itself into processes of a quasi-economic character. Psychological like physiological "processes," involve effort, steady application, and capitalisation of results under constant reliance upon widely and permanently useful correlations and correspondences. In other words, "acquisition" of mental, like that of physiological or mercantile capital, is due to work, coupled with the "live and let live" principle. As in the case of the fruit and the attracted animal, the "object" lending itself to the application of the mind, is generally one that has had in many ways adequate preparation fitting it for reciprocal intercourse with another being.

Some of the simplest elements are now coming to be spoken of as "biologically inclined," which is as an earnest of the primordial and often hidden forms of mutuality on the existence of which I insist. Quite recently a thesis has been propounded by an American writer, Professor L. J. Henderson, in his *The Order of Nature* to the effect that the properties of the three elements—Hydrogen, Oxygen and Carbon are somehow a preparation for the evolutionary process.

We may say that even the most difficult psychological "processes" are merely complications superposed upon primitive

reciprocal and quasi-economical processes, such as those by which the simplest elements are held together in protoplasm. Instead of positing, however, as a correlate of such a view, a purely teleological order of Nature, as others have done, we shall merely say that the apparent "preparation" of the life-elements for "ultimate purposes" amounted to this: that all equilibria, systems or unions, came by their properties and permanence through serviceableness, *i.e.*, in proportion as they availed towards life in the cosmic scheme of things. The wonderful properties of the elements, so we shall argue, are the expression of their wide, cosmo- and bio-economic usefulness acquired during milleniums of exercise and application in cosmic service, when they "learned" that they must do unto "others" what they wished others to do unto them, *i.e.*, to be of service, or, at any rate, in Kant's terminology, to act according to "maxims" which in the interest of all alike, required to be universalised, *i.e.*, according to "duty," in the cosmic sense of the word. The superficial thinker would see only selfish and purely subjective interests at play in the case of, say, an animal attracted by a seed or a luscious fruit, which it forthwith "devours." It is precisely in pursuance of their selfish interests, so he would say, that animals have developed their peculiar and "grasping" mentality, which differentiates them so pronouncedly from the meek flower.

But the case is not so superficial as this. Had it not been for the operation of primordial forms of Symbiosis and the capital and momenta thereby established, the useful differentiation between plant and animal, as we know it to-day, and the concomitant bio-economic exchange of substances and services between the "kingdoms," would never have been possible. A common descent, protoplasmic kinship, ever renewed by continuous Symbiosis, and a persistent common cause, these are the powerful and perennial forces behind the mutual "interest," the mutual "appeal" and the mutual stimulation between plant and animal. Wherever we find latent possibilities of "appeal" and in especial of "lively" interaction, we may conclude that they are similarly to be accounted for by previous history and by correlated evolution.

The superficial thinker overlooks these important data and the further fact that, in the normal growth of biological mutual-ity, a kind of collective usefulness has become operative. The

ensemble of plants acts as a useful and indispensable complement of the *ensemble* of animals. Once such collective usefulness was soundly established, its very success led to many temptations. It became possible for some species to abandon the road of biological rectitude and for a time to flout the bio-moral principle of co-operation. Yet the mere possibility of such a disastrous course is no justification, as I believe I have shown, for the view that non-reciprocal methods are in any real sense successful or superior methods.

Considering that the truly integrative, *i.e.*, symbiotic, principle has so long been overlooked, it cannot cause wonder that a most vital question of Psychogenesis has not even been mooted, namely, as to whether our physiological complement, the plant, acts also in an important manner as our psychological complement. Are we in any sense plant-inspired, just as we are to a large extent plant-fed and plant-“respired”? Is our thinking to any important degree directly determined by the plant? There seems no lack of evidence to show that there is a profound connection between brain and food. According to Bechstein,* in Germany, young bull-finches that are to be taught to sing particular tunes, must be taken from the nest when the feathers of the tail begin to grow, and must be fed *only on rape seed* soaked in water, and mixed with white bread. Instruction is said to succeed best when infused, as it were, with such food. The finches learn those airs most quickly and remember them best which they have been taught immediately after eating *their special food* (cross-food).

The honey-bee, a symbiotic cross-feeder *par excellence*, with a relatively high development of intelligence is a further example of what I mean. It seems to draw in its “wisdom” with the food. There is also the case of the honey-ants.

These ants (says Mr. P. Leonard in the *Scientific American*, Supp. 9th December, 1916), do not display such a wolfish eagerness to acquire chance scraps of food, as is shown by other species, who live from hand to mouth. Theirs is an inoffensive character. Mr. Leonard goes on to say that whilst among the solitary insects, such as the flies, the moths and beetles, only a very small percentage of their numerous offspring ever reach maturity, owing to parental neglect, “among ants, under favourable conditions, the infant mortality is practically *nil*.”

We are further told: The “ants have shown the possibility

* “*Habit and Instinct*,” Lloyd Morgan, P., 176.

of a perfect communal life, and have proved that individuals can be incited to the maximum of effort with the minimum of personal advantage, and that the little states, based upon unselfish sisterhood, are supremely fitted to survive in the struggle for existence." What Mr. Leonard has entirely overlooked, is that the good results emphasised by him are incompatible with any other basis but that of cross-feeding. He speaks of the "dissolved" personality of the ants, which reminds us of the late Professor W. James's suggestion that reality exists distributively.

Professor James borrowed his idea as regards the distributive existence of reality from Fechner, who, as we saw, regards the earth as the grand matrix of all organic life and reality, and looks upon the whole animal and vegetable kingdoms as indissolubly inter-evolved and interlinked and forming with the inorganic systems of our globe a purposefully inter-linked whole. We found that there is indeed good reason to see a double concord between man and the earth, and between man and the plant—an essential and orderly inter-linking of life, organic and inorganic, in cosmic evolution. We found, on the other hand, that a divorce from Symbiosis cuts off a species from this essential order of Nature. There seems to be justification for the view that such a divorce cuts off a species also from reality, *i.e.*, from its natural psychological and moral sources. We shall thus indeed reach a similar view to that entertained by the Stoics, namely, that the reason in man's soul is all of one stuff with the Reason governing the universe—the chain of transmission being provided by Symbiosis.

Reverting now to the science of Psychology, it was quite recently stated by Dr. G. W. Cunningham in his *Creative Will* that our aims and tendencies dig the channel in which the stream of conscious experience flows, which is not a bad metaphor to use, in so far as it at least calls to mind the need of steady effort in the accomplishment of progressive Psychogenesis. Again it must be urged, however, that there must have been throughout the ages some tendency or principle which kept the aims and tendencies of organisms mainly on the path of useful conduct—conduct, that is, which in the widest sense avails towards life. What a woe-begone entity our consciousness would be, were it at the mercy of aims and tendencies irrespective of such usefulness. Samuel Butler, who looked upon mind as the cement in the succession of generations, insisted on the

existence of some definite principle capable of acting as a rudder and compass to the accumulation of variations. He would, no doubt, were he still alive, be one of the first to welcome the principle of Symbiogenesis as capable of accomplishing such direction of evolution, both physiological and psychological.

Again, Psychologists consider that "perceptions" are the result of "acquisitions." "There is every reason to suppose" says Professor James Sully in his *Outlines of Psychology*, "that this simple act of referring impressions to things or objects in space is the result of a long process of acquisition or learning by experience."

Sensations are interpreted by an act of perception, or, in other words, they are "worked up" as an element into that compound mental state which is called a percept.

There obtains in fact, as has sometimes been remarked, a kind of mental "alchemy." This "alchemy" I affirm, is intimately connected with "industry." I look upon mental acquisitions as a kind of funded wealth, built up by mental work and the capitalisation of its results. The legitimacy of the "capitalisation" depends upon bio-economic and bio-moral factors.

The mind is said to grow by what it assimilates. I would urge in this connection that the symbiotic relation with its need of industrious habits rivets the attention of the mind upon reciprocal activities and thereby tends to fix a corresponding state of mind—a socialised mind, as it were, which we have already found to be the *sine qua non* of psychological progress. There is nothing like symbiotic endeavour to feed the mind and to regulate mental developments in a salutary and permanently useful manner.

It was shown in a previous chapter that a great deal of prejudice had yet to be got rid of as regards the best methods of feeding plants, particularly if we wish to aid the real welfare and evolution of the plants rather than merely exploit them for our immediate purposes. In the past, anything seemed good enough for the plant so long as it afforded stimulation for rich and luxurious productions, irrespective of the ultimate interests of the plant. "Was gut stinkt, das gut duengt." Only recently it has dawned upon us that a plant is, like ourselves, under delicate laws of life and of health, and, further, that in its "assimilations," as in ours, it is quality rather than quantity that counts. This

case of assimilation is somewhat similar to that of mental assimilations. No doubt, discrimination must be increasingly our watchword in the future. It cannot be insisted upon too much that symbiotically disposed organisms enjoy an immense advantage over non-symbiotic in that they receive the best regulated, the most directly effective, pabulum for body and mind, which not merely sustains the life of the species, but assists also progressive evolution. This is quite the opposite to what happens in the case of non-symbiotic species. The fact is incontestable that, other things equal, the symbiotic everywhere vastly outstrip the non-symbiotic and predaceous organisms in those mental, moral, and æsthetic achievements that count in progressive evolution. In our climate, for instance, the chances of survival are infinitely better for those animals that rely upon the surplus stores of the plants than for those that seek their provender predaceously among living organisms. In the winter time, as Mr. G. G. Desmond lately reminded us, insect fare being "off," the animals that feed on insects are palpably worse off than those that feed upon hard fruits and grain. The latter have made their winter store, and may remain awake and active enough to go out and about on fine days.

Surely the chances of fruitful social and mental life are, therefore, higher amongst cross- than in-feeders. From the storage of food-supplies for the winter it is not a far step to the formation of intellectual habits, which, as Professor Sully tells us, aid in their turn the increase of facility in acquiring and reproducing new knowledge. The cross-feeders, therefore, other things equal, must excel in "Plastic power of the Brain." Their brain is healthily occupied and is fed in accordance with the requirements of wholesome and widely useful efficiency, whilst that of carnivores is occupied with theft and murder and fed in accordance with the requirements of selfish efficiency, which is productive of lop-sided developments, such, for instance, as disproportionately long fangs, which may require such extravagant supplies of blood for their maintenance as to inhibit valuable supplies from reaching the brain as they otherwise might have done. It would be strange, moreover, if the fruits of genuine biological partnership, *e.g.*, the spare food-substances of plants, were not also instinct with many direct and wholesome psychic influences, which carnivores are obliged to forego.

To take another tenet of Psychology: We are told that as a

condition of the reproduction of mind-images there must be "depth of impressions," and there must also exist a further circumstance, known as "the force of association." "Most of the events of life," so we are told, "are forgotten just because they never recur in precisely the same form. The bulk of our mental imagery answers to objects which we see again and again, and events which repeatedly occur." "The more frequently an impression is repeated, the more enduring will be the image. Where the repetition of the actual impression is impossible, the repeated reproduction of it serves less effectually to bring about the same result."

Again we meet with the important pre-requisite of "permanence" in the growth of mind. As before, it clearly emerges that social interaction is the most effective means of building up mind. We may once again conclude that nothing so much as systematic biological co-operation could have produced the right psychological foundation of the human mind. Repetitions and mere frequency of impressions *per se* cannot be looked upon as sufficient; for they are not by themselves guarantees of survival capacity. It is necessary that the respective activities be of a "right" kind, *i.e.*, sanctioned by the biological use they serve. We shall see presently that not only regularisation and due frequency, but also due limitation of sense impressions is necessary to produce desirable permanent effects, and this precisely as though the conditions generally desirable to achieve really "good" psychological results in the case of man were also those required for the purposes of Symbiosis, with its *sine qua non* of moderation. Obviously again, the hazards and vicissitudes of the savage and predaceous life cannot supply conditions the equals in general beneficence of those furnished by the symbiotic life with the regularity, health and security that it entails.

The increase of brain power is recognised to be due to exercise, and this, according to Professor Sully, implies two things:

(1) All brain activity reacts on the particular structure engaged, modifying it in some unknown way and bringing about a subsequent "physiological disposition" to act in a similar manner.

(2) In the second place we have to assume that different parts of the brain which are exercised together acquire in some way a disposition to conjoint action.

Again we get effort, specialisation and capitalisation—the solution of the economic problem in the psychic sphere of life. Something of value is to be acquired, to be increased and preserved—entailing labour, division of labour, avoidance of waste, summation of powers, capitalisation and values. The brain is known to be the seat of important bio-chemical “processes,” and these may be viewed as having the effect *inter alia* of fitting all parts of the body increasingly as bio-economic agents. When we get “exercise” and resulting “disposition” we are not far from “right” exercise and “right” disposition, in accordance with the bio-economic explanation so far adduced. The dominant bio-chemical directions are always those given by Symbiogenesis. That is to say, that work and mutual evolution are the secrets of bio-chemical potency, and a common organic or cosmic interest is the secret of the dominance of “right” exercise and “right” disposition.

We can trace in the laws of pleasure and of pain the same sequences as in the development of mind. This is what Professor Sully says :

Psychologists have long endeavoured to bring all the varieties of pleasure and pain, bodily and mental, under certain laws. Although they cannot as yet be said to have perfectly succeeded, they have formulated one or two principles which appear approximately correct, and which are of some practical consequence. Of these the principal law may be called the Law of Stimulation or the Law of Exercise. All pleasure is the accompaniment of the activity of some organ which is connected with the nerve centres, or the seat of conscious life. Or, since this activity has its psychical concomitant, we may say that all pleasure is connected with the exercise of some capability, faculty, or power of the mind. And it will be found in general that all *moderate stimulation* of an organ, or all *moderate exercise* of a capability, produces pleasure. (Italics mine.)

I have already alluded to the operation of a law of “symbiotic moderation” and to its importance in life generally. Here we have further confirmation of its importance from the sphere of Psychology. We see how fundamental and essential indeed is the factor of moderation, which, surely, must never be left out of account in Qualitative Biology. It now becomes more emphatic that all successful association indispensably requires moderation. Adequate stimulation, moderate exercise, moderate appetites, yet continuous application withal,—“Ohne Hast und ohne Rast”—these are the qualifications needed for

a healthy, pleasurable and successful life, as for a successful accumulation of variations.

Samuel Butler was among the first writers on Evolutionary Psychology to adumbrate the "thoughtfulness of food." If it was not given to him to reach the bio-economic interpretation of evolution, he at any rate hinted that evolution had a moral basis. Just as he declared, respecting the pioneers of "Evolution," that they had been too busy proving that organisms had descended with modification at all, to give due attention to the particular factor of mind, so it may be said of him, that he was too busy vindicating the general claims of mind to go beyond this task and tackle the matter of the needed qualifications. It became clear, however, from his contribution to the subject that a vast array of facts concerning mental evolution remained to be deciphered. There was, first of all, the great question of memory, of the mechanism of handing on habits and instincts, a subject to which Butler more particularly addressed himself, and which may be fitly touched upon here.

Sir Francis Darwin, as President of the British Association, 1908, conceded that

A plant has memory in Hering's and Samuel Butler's sense of the word, according to which memory and inheritance are different aspects of the same quality of living things.

This view of memory gains in exactness if we supplement it by bio-economic considerations. For, is it not that the fundamental quality in virtue of which the plant "stores" memory, *pari passu* with other important organic capital, may justly be viewed as an essentially economic quality, which, moreover, was never totally unconnected with the needs of the biological community? The storing of even the most fundamental sense impression for racial purposes entails work; and it is the capacity to perform such work which really lies at the root of other useful qualities, of memory and of heredity generally. The psychic life of the plant is, therefore, pre-eminently bound up with work, which is the grand regulator of all consciousness, and which provides certainly one of the keys to an understanding of the phenomena of memory. Once mind is thus conceived as correlated with work, it is possible to amplify considerably Sir Francis Darwin's further statement, made on the same occasion, that "Evolution now becomes definable as a process

for drilling organisms into habits and eliminating those which cannot learn."

We might ask this: Who are those "which cannot learn?" Are they such as have never "learnt," whose ancestors had never "learnt?" Or have they at one time or another stopped "learning," thus coming through disobedience to a sociological and quasi-moral law, under the penalty of elimination? Thanks to Bio-Economics, we can now say with a clear conscience that evolution is a process for drilling organisms into "good" habits and disqualifying and penalising those which, in disobedience to the bio-moral trend of things, nevertheless allow themselves to lapse into "bad" habits. "Learning" depends upon the power of profiting by, and storing up the results of, experience; on the power of forming "perceptions" of some kind; all of which in turn depends upon the "working up of sensations," the pre-requisite throughout being: definite, moderate, and systematic activities of the nature of industries, and a faithful maintenance of wholesome activities. All of which, again, requires definite economic and biological associations of a permanent character, which, as we have seen, only widely useful organisms can afford to entertain.

Our assumption that the plant plays an important rôle in the evolution of mind, gains in strength with every fresh discovery of substances potent in animal life and co-evolved by the plant in the course of co-operative evolution. Such discoveries are multiplying fast and coming to the front, similarly to the way in which the importance of the biological as the chief causative factor in evolution generally may be said to have come into prominence. There can no longer be any doubt that a wholesale re-interpretation of Biology is rendered necessary by the discovery, for instance, of such important symbiotic agents as the body-defending Phagocytes, of the agriculture-sustaining, nitrifying Bacteria, of the "disinfectant" micro-organisms, of the indispensable, life-giving Vitamines—all anti-thetic in action to the non-symbiotic or pathogenic micro-organisms, or to the death-dealing alkaloid substances, for instance. The number of "deficiency diseases," due to the absence of Vitamines in the diet, is seen to be greater than at first thought. Says Dr. F. M. Sandwich in the *Lancet* (23rd October, 1915): "Slowly and laboriously, we have learnt that under the essential needs of an animal's diet are organic

substances, so small in amount that they may be easily overlooked by the chemist and wholly unsuspected by the physician."

The plant alone possesses the secret of the manufacture of Vitamines. A vast amount of the right kind of experience and of the right kind of " learning " must have preceded the due establishment of the plant's subtle bio-chemical and psychogenetic powers.

CHAPTER V

THE "INTELLIGENCE" OF PLANTS

Plants have a logic of their own and act on it, just as we do, so that we cannot dispute their intelligence.—*Le Dantec*.

How then are we to assess the plant's part in Psychogenesis? What, first of all, are the achievements of the vegetable world in the way of "mind"? There exists but scant literature on the subject. Fechner has written some good chapters in estimation of the plant's general status, conceding a relatively high place to its "mentality." More recently, Prof. Henri Bergson has expressed the view, now widely entertained, that the plant is characterised by a consciousness asleep and by insensibility; the animal showing by contrast sensibility and awakened consciousness. Some fifty years after Fechner, however, M. Maeterlinck published a stimulating essay on *L'intelligence des Fleurs*, which, based as it is on the most up-to-date knowledge of plant life, lends itself well to an examination of the subject.

Maeterlinck, be it premised, as he is at pains to insist himself, has written according to evidence, and by no means according to romance. True, he has taken up a subject long left to imagination, but he wishes above all to appeal to reason. It would be difficult to realise, he tells us, unless one had studied Botany a little, how much of imagination and of genius lies hidden amidst all that verdure of plant life which is so pleasing to the eye. The more we study the doings of the plant, he continues, the more we find that it sets a prodigious example of self-reliance, courage, perseverance and ingenuity. He thinks that plant intelligence arose out of the need of movement and out of the "appetite for space." In his own words:

This need of movement, this craving for space, amongst the greater number of plants, is manifested in both the flower and the fruit. It is easily explained in the fruit, or, in any case, discloses a less complex experience and foresight. Contrary to that which takes place in the animal kingdom, and because of the terrible law of absolute immobility, the chief and worst enemy of the seed is the paternal stock ("souche"). We are in a strange ("bizarre") world, where the parents, incapable of moving

from place to place, know that they are condemned to starve or stifle their offspring. Every seed that falls to the foot of the tree or plant is either lost or doomed to sprout in wretchedness. Hence the immense effort to throw off the yoke and conquer space. Hence the marvellous systems of dissemination, of propulsion, and navigation of the air which we find on every side in the forest and the plain; amongst others, to mention in passing only a few of the most strange, the aerial screw or Samara of the Maple; the bract of the Lime tree; the flying machine of the Thistle, the Dandelion and the Salsify; the detonating springs of the Spurge; the extraordinary squirt of the Momordica; the hooks of the eriophilous plants; and a thousand other unexpected and astounding pieces of mechanism; for there is not, so to speak, a single seed but has invented for its sole use a complete method of escaping from the maternal shade.

There is, no doubt, a great deal of truth in Maeterlinck's view. Necessity, *i.e.*, the elementary need of the plant, has been the mother of its inventions, and such necessity has proved a most auspicious opportunity for the inauguration of a method of organic reciprocity which again has been the origin and the mainstay of the greatest goods and blessings of life. Great as are the mechanical achievements of the plant, so eloquently acknowledged by Maeterlinck, greater far, and more important, are those which may fitly be called its bio-economic achievements, however accidental the causes that gave them birth. For it was the latter kind of achievement which equipped the plant for a high position in life, far transcending in importance the conquest of space, namely, the position of indispensable pioneer and main supporter of organic civilisation. More particularly, if we remember that the primitive bacteria already made use of the method of Symbiosis, and that this rendered possible the appearance of the higher plants, there seems to be every justification for giving pride of place to the bio-economic rather than the purely mechanical achievements of the plant, wonderful though these be. Nay, we are justified in assuming that the organic and psychical funds necessary for the engendering of some of these inventions, have to a large extent been derived from biological reciprocity. This undoubted symbiotic origin of many plant capabilities must not be overlooked. It is a case of "inheritance affording the means by which inheritance is improved," a statement that I have culled from a review by Prof. J. Arthur Thomson of a book on animal behaviour, by Dr. S. J. Holmes (*Nature*, 24-5-17).

We have seen that plants relatively backward in Symbiosis,

like some of the wind-fertilised weeds, for instance, are apt to be noxious, though, no doubt, they still fill an important place in the Economy of Nature. Whether a plant relies upon physical or biological agency for the conquest of space, its chief reliance must always be upon service. It is this alone which gives sanction and status. Ability to rely upon duly remunerated biological agency, moreover, makes possible a progressive avoidance of waste of energy on the part of the plant and a corresponding better endowment of the protoplasm and the seed both for "home" and for "export" purposes. We may, therefore, amplify Maeterlinck's remarks thus: Plant-intelligence arose out of a double necessity (1) to provide for its own immediate needs and (2) to supply at the same time, and in a progressive manner, the needs of "organic civilisation." This explanation will be seen to remove much of the apparent "strangeness" of the plant's world. The plant's limitations may now be viewed as those of a specialist in division of labour; they are seen to be essential to the success of the whole organic family, and thus to entail in the end great compensations to the plant. The very limitations of symbiotic partners, as we have recognised, in the end make for psychical progress. It cannot be emphasised enough, therefore, that the achievements of the plant, referred to by Maeterlinck, as well as the apparently strange vicissitudes of the plant world, must be viewed in the light of Bio-Economics.

Maeterlinck speaks of a mysterious law of "destiny," or of "fate," by which, he thinks, the plant is ruled. I should say, on the contrary, that the plant is exemplary of the way destiny should be controlled by the organism, though in obedience to the bio-moral law. My interpretation sees in the momenta created by symbiotic systems the main directive force of progressive evolution, towards the establishment of which force all organisms, though in different degrees, contribute their quota. There is no need to postulate any "destiny" or "fate" on this view. Organisms which weary of service or flout the symbiotic relation, are themselves to be blamed, as it were, for their degeneracy.

Again, what are the circumstances under which, as Maeterlinck says, a plant may "lose its head." They are precisely those equivalent to a loss of "symbiotic sense," which sense is the source of all orientation and of all knowledge of relatedness in the world of life. I have shown in previous chapters that

Domestication and Cultivation, in so far as they cut off the organism from its natural symbiotic bonds very generally induce a "misère physiologique." It is not surprising to find that the respective symptoms are often attended by those of a "misère psychologique." This is how Maeterlinck puts it: "On dirait que la plante cultivée perd un peu la tête si l'on peut s'exprimer ainsi, et qu'elle ne sait plus au juste où elle en est."

The explanation of a loss of "symbiotic sense," however, will be found to be more scientific and more exact.

An example from animal life, showing a psychological *misère* arising from illegitimate biological relations, is presented by the case of the hermit crab, infected by the parasite *Sacculina*. It was shown by the late lamented Geoffrey Smith that in crabs of both sexes so infected the cyclical changes of reproduction and of growth occurring normally in animals do not take place. Such crabs neither grow, moult nor reproduce. There is sterility and apparently loss of proportion generally caused by the predominance of a parasitic relation. The psychological "yield" here obtained is one the opposite of that obtained under a symbiotic relation. And it is the same with over-exploited plants.

My repeated emphasis of "symbiotic disposition" and "symbiotic sense" might well have caused the reader to reflect on the evidence of the alleged endowment of organisms. I maintain that there is abundant evidence showing the existence of such a sense. The various "instincts": of association, of reciprocity, of self-sacrifice, of parental care of offspring, of solidarity and of altruism, all, I claim, are to be classed under this heading.

It is customary to speak of the primordial distinction between plant and animal as due to the "choice" made by the plant in favour of an energy-storing life whilst the animal is represented as having "preferred" the life of mobility. One might think that mutuality had played no part in this alleged "separation," which is yet no separation, but only a more extended union—a more extended Symbiosis, which has led to all that is great and desirable in our lives. I see in the retention of the vital connection between the kingdoms, above all, evidence of the symbiotic sense, the natural development of which favoured the widest forms of reciprocity and of division of labour as between plant and animal. And how otherwise than actuated by the symbiotic

sense have the bulk of strenuous orders, genera and species of plants kept to the path of bio-economic usefulness—difficulties and biological temptations notwithstanding, and have made their great sacrifices for the attainment of cross-fertilisation, by means of which they have achieved not only a higher status for themselves but also conspicuous service to the world of life? How have they “learnt” to “recognise,” as Maeterlinck puts it, that self-fertilisation conduces to degeneracy?

à la suite de quelles expériences innombrables et immémorables ont-elles reconnu que l'auto-fécondation, c'est-à-dire la fécondation du stigmate par le pollen tombé des anthères qui l'entourent dans la même corolle, entraîne rapidement la dégénérescence de l'espèce?

It is begging the question, as Maeterlinck rightly insists, to say that the force of circumstances has eliminated those plants that did not do what was somehow required of them. Even though we give some place still to “chance,” it is necessary to recognise that there must be a reason for the rise of some species and the fall of others. The explanation, on my view, is none other than that some species did, and others did not, preserve the integrity of the symbiotic sense—the necessary endowment of a useful member of a co-evolved biological community. To say that the plants have recognised nothing and that the force of circumstances has eliminated some in favour of others, is halving and unduly externalising the problem of survival. To say that the plants recognise everything and that memory is everything, is equally halving the problem by unduly internalising it. What the plants have experienced in constant laborious contact with the environment, they have capitalised in the form of symbiotic sense. The behaviour of plants thus has to do with consciousness, though they be not directly conscious, as we sometimes are of our doings, of all they do; it has similarly to do with Bio-morality, though they be not consciously moral as we are.

What is required of the plants, in the interest of organic life, is that they follow in the main the guidance of their symbiotic sense, *i.e.*, that they retain a tolerable degree of co-operative usefulness. Such obedience to bio-economic law, and not the uninspired weeding out by “Natural Selection,” assures their continuance.

The case of disobedience to the bio-economic law of Symbiosis, as instanced by Degeneration and Parasitism, clearly shows a disintegration of the symbiotic sense. Sir E. Ray Lankaster

long ago pointed out that in Degeneration the suppression of form corresponds to the *cessation of work*, that the "lower" condition *incidental upon Degeneration* is due to the organism being fitted for less complex action and reaction in regard to its surroundings and that the "*habit*" of Parasitism, for instance, clearly acts upon animal organisation in the same way as we see an *active, healthy man sometimes degenerate*, when he becomes suddenly possessed of a fortune, or as Rome degenerated when possessed of the riches of the ancient world. He adds that wherever we see symptoms of parasitism and of sluggishness, as expressed by "*habits*," we are justified in applying the hypothesis of Degeneration. I have italicised some of Sir E. Ray's remarks to indicate that the identical economic and psychological sequences apply universally and above all that we have in Degeneration a disintegration of a previous sense of work, of service, of orientation and of "responsibility." Maeterlinck expresses wonderment at the essential knowledge, evidently engendered by the symbiotic relation, thus :

Shall I speak of the seeds which provide for their dissemination by birds and which, to entice them, as in the case of the Mistletoe, the Juniper, the Mountain-ash, lurk inside a sweet husk ? We see here developed such a powerful reasoning faculty, such a remarkable understanding of final causes that we hardly dare dwell upon the subject, for fear of repeating the ingenious mistakes of Bernardin de Saint-Pierre. And yet the facts can be no otherwise explained. The sweet husk is of no more use to the seed than the nectar, which attracts the bee, is to the flower. The bird eats the fruit because it is sweet and, at the same time, swallows the seed, which is indigestible. He flies away and, soon after, ejects the seed in the same condition in which he has received it, but stripped of its case and ready to sprout far from the attendant dangers of its birth-place.

I shall be glad if anyone will produce a better and more rational interpretation of these phenomena than the socio-physiological one for which I contend. This interpretation, moreover, enables one to understand how the plant is able to communicate a share of its vital psychic equipment to the animal, fitting it in many ways for the purposes of organic progress. When so much that is good is seen to arise from the symbiotic relation, and when the plant in particular is seen to be, not only the fundamental capitalist, but also the fundamental inventor and contriver of service, the assumption is by no means fanciful that the plant is also a direct sustainer of animal intelligence. The animal takes in "knowledge" with its food, as it were—essential

"knowledge"—which is "pre-digested" by the plant. What is the essence of this "knowledge"? Is it sense-knowledge? It is; but of sense tempered by service and, hence, making for vital perceptions and vital knowledge. We can thus see reason for the observation made by an American writer, John Dewey, that "it is not we who think in any actively responsible sense; thinking is rather something that happens in us." Some thinking at any rate, I should say, somewhat passively happens in us; for thought processes would seem to begin with the plant, to be carried a stage further by the animal. A great deal of essential thinking in the world would seem to be performed distributively as between symbiotic partners.

The idea of this dependence of mind upon the co-operation of the lowly plant, of course, is one apt to grate on our pride. But we must not allow pride or prejudice to deter us in our quest of truth.

I have been told recently by a critic that Prof. Bergson has given a much clearer exposition than is to be found in my book on *Symbiogenesis* of the relations between the plant and the animal kingdoms. That may be so. One thing, however, is certain, namely, that Prof. Bergson's is not a bio-economic interpretation of evolution. Far from it. He is, of course, obliged to admit the existence of various systems of mutual service between plant and animal, and between higher plant and bacteria. He specially repudiates, however, the term "division of labour" as giving no exact idea of evolution, such as he conceives of it. Bergson thinks that harmony between plant and animal existed only at the start of evolution, which subsequently was "discontinuous" so far as complementary processes are concerned; and, in his opinion, sexual generation is perhaps only a luxury for the plant—though he is willing to admit that it was a necessity to the animal. Evidently this is disregarding the whole significance of bio-economic services and of the vast system of inter-action upon which evolution is based. It was shown in *Symbiogenesis* that sexual reproduction represents the highest form of domestic Symbiosis, that it in turn depends upon the highest forms of biological Symbiosis, and further, that we have to regard the sexual generation of the plant not as a luxury, but as an important and indispensable forward step progressive evolution. It was shown at the same time that the economic laws of Nature are eternal, and that the only luxury

she sanctions is, in Ruskin's words, an innocent but exquisite luxury, namely, luxury for all by the help of all.

The harmony which Prof. Bergson thinks existed only at the beginning, has, in my view, never been discontinued. On the contrary, it became ever more effective though under different forms. The more perfected partners merely betook themselves, as advanced "specialists," to wider fields of action. They "relied" in the main upon the integrity of the symbiotic sense. What Maeterlinck calls the "foresight" of the plant is thus a close associate of the symbiotic sense equipped with which the plant is able to gauge the needs of the partner by "intuition" as it were—a direct way of the "mind" to arrive at conclusions.

The case here made out for Plant Psychosis may not inaptly be summarised by the German saying: "Wem Gott ein Amt giebt, dem giebt er auch Verstand." Maeterlinck almost hints that animal intelligence may have been derived from plant intelligence, as the more fundamental and original of the two. He says this:

In a world which we believe unconscious and destitute of intelligence, we begin by imagining that the least of our ideas created new combinations and relations. When we come to look into things more closely, it appears infinitely more probable that it is impossible for us to create anything whatsoever. We are the last comers on this earth, we only find what has always existed and, like astonished children, we travel again the road which life has travelled before us.

Every flower has its idea, its system, its acquired experience which it turns to advantage. When we examine closely their little inventions, their diverse methods, we are reminded of those enthralling exhibitions of machine-tools, of machines for making machinery, in which the mechanical genius of man manifests all its resources. But our mechanical genius dates from yesterday, whereas floral mechanism has been at work for thousands of years. When the flowers made their appearance upon the earth, there were no models around them which they could imitate; they had to derive everything from within themselves.

The latter part of the statement is, of course, challengeable; for we know now that the higher plants were preceded by bacteria which at any rate devised many primitive mechanisms of work and even the methods of Symbiosis, in virtue of which they could supply a prime need of higher plants, namely, Nitrates. The plants, therefore, did not devise everything spontaneously from within themselves. They derived inspiration from helpers.

Maeterlinck has, however, a special passage in which he shrewdly hints at the existence in Nature of some such principle

as the bio-economic law of Reciprocity. Speaking of the lucerne's "search to ensure its future," he says that the plants having been deceived in the spiral, the yellow lucerne added pits or hooks to it, "saying to itself, not unreasonably, that since its leaves attract the sheep, it is unavoidable and right that the sheep should assume the care of its progeny."

"And lastly," he continues, "is it not thanks to this new effort and to this happy thought that the lucerne with yellow flowers is infinitely more widely distributed than its sturdier cousin whose flowers are red?"

I would only add the explanation that the fact of the lucerne's leaves being attractive to the sheep is not an accident, but is closely connected with those fundamental symbiotic amenities that keep going the life of plants and animals alike. We need not impute Maeterlinck's identical reasoning to the plants, so long as we make allowance for the existence in plants of a symbiotic sense, with all it entails in Bio-morality.

Again, in the case of the lettuce, Maeterlinck adduces an example showing how essential is the recognition of the concepts of biological "right" and biological "duty." The cultivated lettuce is one of the plants that have ceased to defend themselves. In its wild stage, if we grow a stalk or leaf, we see a white juice exude from it, the latex, a substance formed by various matters, which vigorously defend the plant against the assaults of the slugs. On the other hand, in cultivated species derived from the former, the latex is almost missing, and they fall a prey to slugs.

Shall we not say that it is indeed the duty of the cultivator to defend the cultivated "specialised" form in return for extra services received and in accordance with the unwritten laws of Symbiosis? Every new symbiotic relation, I contend, requires new and redistributed services, as it brings in its train new organic forms. The case is not dissimilar to that of new discoveries by man, which, as Prof. Bergson believes, are often instrumental in producing new types of humanity.

Although more than once approaching the recognition of a bio-economic law of reciprocity, Maeterlinck however does not see clearly enough to follow up the threads consistently. He goes off instead at a tangent, identifying the sober symbiotic needs of cross-fertilising insects with the "passions" of others, and interpreting the laws of "organic civilisation" as "destiny."

Speaking of the wonderful mechanism for cross-fertilisation in the case of the Orchid *Coryanthes macrantha*, he tells us :

Here, then, we have a flower that knows and plays upon the passions of insects. Nor can it be pretended that all these are only so much more or less romantic interpretations ; no, the facts have been precisely and scientifically observed and it is impossible to explain the use and arrangement of the flowers' different organs in any other way. We must accept the evidence as it stands. This incredible and efficacious artifice is the more astonishing inasmuch as it does not here tend to satisfy the immediate and urgent need to eat that sharpens the dullest wits ; it has only a distant ideal in view ; the propagation of the species. But, why, we shall be asked, these fantastic complications which end only by increasing the dangers of chance ? Let us not hasten to give judgment and answer. We know nothing of the reasons of the plants. Do we know the obstacles the flowers encounter in the direction of logic and simplicity. Do we know thoroughly a single one of the organic laws of its existence and its growth ?

As I have said before, I do not think that the glory of the romance involved in the mutual relations between plant and animal, is in any way lessened by the discovery that the plant in no way lives by itself or to itself, and that the great majority of its wonderful contrivances are "designed" to effect a bio-economic utility whilst subserving at the same time the more self-regarding purposes of Nutrition and Reproduction.

Maeterlinck commits himself to the following statement :

The flowers came on our earth before the insects ; they had, therefore, when the latter appeared, to adapt a totally new system of machinery to the habits of these unexpected collaborators. This geologically incontestable fact alone, amid all that which we do not know, is enough to establish evolution ; and does not this somewhat vague word mean, after all, adaptation, modification, intelligent progress ? It would be easy, moreover, without appealing to pre-historic events, to bring together a great number of facts which would show that the faculty of adaptation and intelligent progress is not reserved exclusively for the human race.

I have already pointed out that the plants were not so unprepared as Maeterlinck imagines, and that above all, they were, in virtue of their past, equipped with a strong symbiotic sense, which is vastly more important than any other inheritance that can be suggested from geological data. The plant's protoplasm was already used to biological co-operation, or "collaboration," as Maeterlinck has it, and it merely developed steadily if gradually along the path of increased collaboration. The plants merely learnt to extend the range and efficacy of

Symbiosis *pari passu* with the growing "beneficent" necessities of "organic civilisation," and they merely helped to "create" the animal kingdom in their own "symbiotic likeness," *i.e.*, according to useful reciprocal differentiation.

There was nothing "unexpected" or sudden in the coming of the animal. Moreover, if the plant had to adapt itself progressively to the rising animal world, so the latter had to adapt itself increasingly to the laws of Bio-morality, conformed to already by the plant, *i.e.*, mainly symbiotic morality. Granted that evolution means *inter alia* intelligent progress, this does not make the term "Evolution" by any means a synonym for "adaptation" and "modification." The latter may be, and often are, the reverse of progress. The vagueness of the term "Evolution" is precisely due to the sophism which I have always combated, of synonymising it with "adaptation" and "modification."

Failing to obtain the concrete footing of Bio-Economics Maeterlinck is inclined to postulate the existence of a "Demiurgos"—a "génie de la Terre," or "Erdgeist," a similar conception to that which attracted Goethe, Fechner, J. S. Mill and William James. This "Demiurgos" would stand in a kind of paternal relation to all of us.

Il use des mêmes méthodes, de la même logique. Il atteint au but par les moyens que nous emploierons, il tâtonne, il hésite, il s'y reprend à plusieurs fois, il ajoute, il élimine, il reconnaît et redresse ses erreurs comme nous le ferions à sa place.—Notre esprit puise aux mêmes réservoirs que le sien. Nous sommes du même monde, presque entre égaux.

As regards intelligence and its distribution, we get a pan-psychic view thus :

It would not, I imagine, be very bold to maintain that there are not any more or less intelligent beings, but a scattered, general, intelligence, a kind of universal fluid that penetrates diversely the organisms which it encounters according as they are good or bad conductors of the understanding. Man would then represent up till now, upon this earth, the mode of life that offers the least resistance to this fluid, which the religions called divine.

Be this as it may, one thing is certain in whatever sphere of life we choose to look, namely, that, other things equal, the best results in evolution accrue from a symbiotic vitalisation of the protoplasm. Just as the symbiotic lichen is capable, in pioneer

fashion, of dissolving the hardest rocks, so the method of biological righteousness generally is the best means of solving the problems of existence. It is as though one could say: Seek ye first this righteousness and all the powers of body and of mind shall be added unto you. *Emitur sola virtute potestas.*

CHAPTER VI

LIFE AND HABIT

That Butler's genius gave him insight into evolutionary problems has been generally, though tardily, recognised.—PROF. J. ARTHUR THOMSON, *Nature*, 10th May, 1917.

IN previous chapters it became to some extent evident that there is a substratum of truth in the Pan-Psychism of Fechner, James, Maeterlinck, and in that of more recent writers, more especially in view of the symbiotic inter-relatedness of beings, which seems to me to represent a very real form of Pan-Psychism.

That there is a concrete form of Pan-Psychism, wholesome or morbid, and of great importance in our daily life, is now more fully to be inferred from a critical examination of Samuel Butler's work on *Life and Habit*, in which he endeavours to propound a pan-psychic view of life.

Butler contends that "Personal Identity" does not exclude the idea that each individual may be manifold in the sense of being compounded of a vast number of subordinate individualities which have their separate lives within him, with their hopes and fears, and intrigues, being born and dying within us, many generations of them during our single life-time. In order to support this proposition, he has recourse to the illustration of the micro-organisms which live within us and which seem, in a general way, to form a part of us and even to determine many of our activities. This is what he says :

These parasites—are they part of us or no ? Some are plainly not so in any strict sense of the word, yet their action may, in cases which it is unnecessary to detail, affect us so powerfully that we are irresistibly impelled to act in such or such a manner ; and yet we are as wholly unconscious of any impulse outside of our own " ego " as though they were part of ourselves ; others again are essential to our very existence, as the corpuscles of the blood, which the best authorities concur in supposing to be composed of an infinite number of living souls, on whose welfare the healthy condition of our blood, and hence of our whole bodies, depends. We breathe that they may breathe, not that we may do so ; we only care about oxygen in so far as the infinitely small beings which course up and down in our veins care about it ; the whole arrangement and mechanism of our lungs may be our doing, but is for their convenience,

and they only serve us because it suits their purpose to do so, as long as we serve them. Who shall draw the line between the parasites which are part of us, and the parasites which are not part of us? Or again, between the influence of those parasites which are within us, but are yet not us, and the external influence of other sentient beings and our fellow-men? There is no line possible.

This passage, then, raises the all-important question of biological relatedness, and it is well calculated to show how greatly the understanding of Pan-Psychism depends upon "Qualitative Biology." I have already emphasised the need of a qualitative Biology and in particular of the inauguration of a standard of biological usefulness with the aid of which to sift the grain of wholesome from the chaff of morbid relations. It is evident that the same reasoning will again prove helpful in dissipating the doubts so widely and keenly felt regarding the nature of our connections with those invisible "parties" and their apparently intangible influences, beneficial or detrimental, to which Butler here refers. First of all, as Qualitative Biologists or Bio-Economists, we shall not fall into the error of applying the term parasite at all in the case of organisms, be they never so small, which contribute in a direct and vital manner to our own health and to the common good of organic civilisation. We shall on the contrary refer to them as symbiotic agents or Symbiotists—sharers in a wholesome Pan-Psychism. We shall discriminate between organisms which, as scavengers, remove the offal of life, rendering themselves indirectly useful, and between rank parasites which lead a wholly non-reciprocal life, living merely destructively on the substance of others—sharers in a more or less morbid Pan-Psychism. Not that we shall lay down any rules of conduct for organisms to obey; but we shall point out the consequences of every method of life, its value in organic civilisation, and we shall discriminate accordingly. The directly useful organisms, be it re-emphasised, flourish and survive in virtue of their continuous usefulness and indispensability which guarantee a super-adequacy of biological supports. Theirs is the method of advance by the summation of powers, of Symbio-Psychism as it were. The survival of scavengers and parasites, on the other hand, is supported only by inferior connections, giving them diminished powers of resistance to disease and lessened survival capacity. Owing to the frailty of life, such organisms as these ever recruit themselves from the ranks of the true

Symbiotists in order to live by the principle of short cuts, which is, however, economically and therefore, in my sense, morally unsound, rendering them liable to the aforesaid weaknesses and to extermination wherever there arises a serious clash of interests with the faithful Symbiotists.

Those beings, then, are truly "part of us" which stand in a directly useful reciprocal relation to us, which relation alone can assure sufficiency and permanence of association. Scavengers are only slightly "part of us" and must not, by over-indulgence or over-work, be allowed to increase their hold upon us. Parasites are but morbidly "part of us," apt, owing to some weakness on our part, to determine us bodily and mentally in a pathological direction. That is to say that beings are "part of us" in very different degrees, from exceedingly wholesome to exceedingly noxious; and it is of vital importance that these differences should be clearly recognised. Contrary to Butler's opinion, it is quite possible to draw the line between real and fictitious partnerships. Butler observes rightly, though but in a general way, that we are to a large extent impelled by our associations to think and to act in their own rather than our interest. Surely then it is incumbent upon us to discriminate between good and bad associations. A man is known by his friends ("Tell me with whom thou hast intercourse and I will tell thee who thou art"). Organisms are largely determined by habits, notably feeding habits, a fact to a certain extent acknowledged by Butler himself when he says, in "Luck or Cunning," that "Eating is a mode of love; it is an effort after a closer union; so we say we love roast beef." Was it not Plato who spoke of the "love affairs" of the body as determining our health, our mental and moral disposition and, ultimately, in the aggregate, the welfare of the city? Was it not the view of the most sagacious of Greek thinkers generally that states perish by various forms of that "excess" which is universally fatal to prosperous action? Has it not been said that "on est aisément le dupe de ce qu'on aime?" And is it not indeed precisely, as Butler almost suggests, that certain feeding-habits involve wrongful biological intercourse?

What is it that can guard us against being "duped" and demoralised by "liaisons" of a biologically undesirable kind? Had Butler been able to answer this question, he would no doubt have given a more practical turn to his Pan-Psychism.

My answer is that our best safeguard is the symbiotic sense, the sense of biological propriety, implanted in us by Nature, which sense ever impels us towards moderation and integrity in all our doings. It is the sense of proportion and of justice, which fundamentally arises from the Psychism peculiar to the symbiotic life. This important sense may be seriously interfered with or jeopardised by false feeding habits. These, as shown before, tend to encourage the idlers and would-be parasites amongst the world of micro-organisms at the expense of strenuous and moderate partners. They tend, in other words, to create a soil favourable to "infection," to distract the existing wholesome influences and in the end to give a new, a pathological turn to our actions and thoughts distorting them in many ways. "For the good which I would I do not: but the evil which I would not that I practise." Once loosened from symbiotic bonds, our former modest associates develop more and more insatiable appetites, the need for the satisfaction of which drives the unfortunate "host" to otherwise involuntary excesses, which render his life increasingly unbalanced and precarious. The unhappy "host" may thus be morbidly impelled, as Plato would say, towards the tyrannical disposition—a curse alike to himself and to the "City." Good health in the case of such a "host" would often seem to depend upon abundant feeding, a "Royal diet," which inference, however, may easily be deceptive, as great supplies are wanted to feed his associated parasites alone. So disgracefully have we, however, become habituated to associate health and even distinction with a pampered state of the body, that we think it most natural for a "fat" man to maintain at the highest pitch the unholy "love-affairs" of his unregulated body. Such and similar discrepancies are in keeping with our social and mental backwardness,—related in turn to our false feeding habits, which rob us of the fruits of a healthy Pan-Psychism. It may be considered as a concomitant of our faulty mentality that orthodox science cannot even tell us what is a standard metabolism or a standard biological relation. Many nutrition experiments produce fictitious results, the appearance of health being falsely taken for the reality, the abuse for the use—*observations provoquées*, as Claude Bernard would say. It is futile, for instance, to expect that a species long used to biological abuse and false feeding and, hence, to many concomitant "special" influences, cravings

and secondary needs, can be found to be happy at once with a suddenly changed diet, however otherwise ideal. The new diet may fail of its usual good effects for no other reason than that it does not provide for the exorbitant "special" or fastidious tastes or "needs" of parasites or quasi-parasities with which the life of the species has, more or less *avoidably*, and more or less pathologically, become associated. It is necessary to recognise the relative indispensability of these doubtful "helpers" to their host, who can no more shake them off than do without them, and who, whilst having to provide for their needs, real or unreal, is being slowly transformed into another being: one of special and abnormal appetites and one involved in the meshes of a morbid Pan-Psychism. "Die Geister die ich rief werd' ich nun nicht los." What we should ask ourselves before experimenting with an organism with a view of establishing a standard metabolism, or a standard food requirement, is this: Who is who? with special reference to associations. In furnishing the pabulum, are we providing for real or for imaginary, for primary or secondary needs, for the needs of a dependent or of an autonomous organism? Surely we cannot take any and every appetite, any and every association for normal! We must recognise, on the contrary, that many relations, however compatible and even indispensable in appearance, are yet unreal inasmuch as they are of a retrogressive nature. The large fangs of the carnivora may be said to be quite indispensable and even congenial to their proprietors, yet by their excessive demand upon the blood-supply, they damage the brain and inhibit progressive evolution and are *pro tanto* (for want of a better term) "diabolically" indispensable or useful. And it is the same with regard to biological relations, many of which are really injurious and belonging to the pathological order, though apparently indispensable to the particular organism.

When one considers how much mankind has yet to learn as regards relatedness and values, one is indeed reminded of the saying of LaoTzù, which seems to have been in Butler's mind often enough, namely, that the truest sayings are paradoxical. The great Chinese sage observes, for instance, that it is the Way of Heaven to take from those who have too much, and give to those who have too little. "But," he continues, "the way of man is not so. He takes away from those who have too little, to add to his own super-abundance. What man is there that can

take of his own super-abundance and give it to mankind? " There is still a lack of righteous and knightly spirit amongst us, and there prevails instead a dangerous tendency to pronounced social antitheses—a world " festering with selfishness," as an American writer recently put it. I believe these shortcomings to be largely due to a false biological basis of life, resulting in a morbid Pan-Psychism, and in a deeply-felt despondency as regards the chances of social salvation by the means that our instincts allow us to command. The Heavenly Way indicated by Lao-Tzù seems beyond our possibilities, because we are not sufficiently inspired from the best, *i.e.*, symbiotic, sources. What man is there indeed amongst us to take of his own super-abundance and give it to mankind?

These are some of Lao-Tzù's recommendations which are well worth re-emphasising: " Those who follow the Way desire no excess." " In governing men and in serving Heaven, there is nothing like moderation. For only by moderation can there be an early return to man's normal state. This early return is the same as a great storage of Virtue. With a great storage of Virtue there is naught which may not be achieved." The great seer of the past thus forestalled the law of symbiotic moderation and distinctly hinted at the truth that the greatest results of evolution spring from symbiotic integrity. By ruling himself frugally and wisely, man determines not to be pathologically, and hence tyrannically, " determined." Man at any rate has it in his power consciously to seek that biological and pan-psyche association, which produces the maximum of individual and social health. He can adopt the standard biological relation. In so doing alone can he, in Lao-Tzù's words, encourage the creation of a great storage of " Virtue," *i.e.*, of cumulative symbiotic sense and lay the foundation for further elevation of the human race. I cannot concur with Samuel Butler in his almost fatalistic resignation on the score of our liability to morbid influences. I cannot agree that we are as helpless or as irresponsible in the matter as he would appear to think. I am not over-awed by the powers of mischief, great though they be, of the micro-organismal world. It would seem to be with the conception of the absolutely small " spirits " as it is with the absolutely large spirit, the " Absolute " of Philosophy. Either is apt to make a bad companion of morality, for this reason, that they make our autonomy look

either too hopelessly susceptible to haphazard interferences or else too hopelessly insignificant by comparison with the will of the Infinite. Fatalism on these scores, however, is no more justified than are the nightmares, or "night-views," as Fechner would say, anent the inevitableness of the "struggle for existence."

It was seen in previous chapters in the case of scientific agriculture, how it becomes increasingly our business in life—and one in which we have every reason to anticipate a fair share of success—to encourage Symbiosis at the expense of its opposite: Parasitism. It is what we are required to do in the interest of our bodily, mental and social health: to encourage Symbiosis rather than Parasitism.

In the case of agriculture we are dealing with vast populations of the soil who are sufficiently inter-dependent with us to allow them to be considered "part of us." Their welfare is as important to us as ours is to them. Here too we have a mutual responsibility, and from this case it is perhaps more generally to be concluded that it is man's true office in the economy of Nature to be in sympathy and in symbiotic league with all "good" beings. As Seneca taught: *Ubicumque homo est, ibi beneficii locus est.*

Butler's treatment, then, of "Our subordinate personalities" requires some essential bio-economic addenda in order to be adequate and complete, and the same must be said regarding his consideration, from his special mnemonic point of view, of the "Assimilation of outside matter," on which subject he nevertheless expresses himself with considerable confidence. He states that

As long as any living organism can maintain itself in a position to which it has been accustomed more or less nearly both in its own life and in those of its forefathers, nothing can harm it.—As long as the organism is familiar with the position (he goes on to say) and remembers its antecedents, nothing can assimilate it. It must be first dislodged from the position with which it is familiar, as being able to remember it, before mischief can happen to it. Nothing can assimilate living organism. On the other hand, the moment living organism loses sight of its own position and antecedents, it is liable to immediate assimilation, and to be thus familiarised with the position and antecedents of some other creature.

This can only mean that a species which has strenuously made a place for itself in the world of life and continues with tolerable

faithfulness to maintain a useful relation with other beings, stands in no danger of being "pensioned off." It will not do to set down race preservation to any other cause than "good" custom, *i.e.*, service and symbiotic integrity, which are the sole guarantees of "good" memory.

Whether or not an organism can maintain itself in a customary position, may be said, in a sense, to depend upon memory, but it must be understood to be a memory instinct with essential knowledge, such as we have seen symbiotic knowledge to be. It is the substance that is wanted and not the shadow, the knowledge and the character rather than the mere remembrance of the past. So in our national life it is the retention of the high character of our forbears that is all-important and not merely the recollection, and glorification of, their deeds of prowess. To say that extinction of species is due to loss of ancestral memory, conveys not much more than the idea that mind must have had some share in the fate of the organism. Let us take a concrete case: the extinction of the sabre-toothed tiger, which had destroyed its customary prey, the giant armadillo, and had become too fastidious to live on any other. Are we to set the fatality down merely to a loss of "memory"? Must we not rather concede that the species, all the time it was indulging in armadillo-feasts, was undergoing a loss of "essential" memory, *i.e.*, the memory of former non-predaceous mammalian food-getting which alone could assure genuine survival? Or could it be argued that the tiger had lost an erstwhile arithmetical rule of its ancestors which consisted in sparing just sufficient armadilloes to prevent their becoming extinct? Who is he who will propound the thesis that a relation so non-symbiotic as that between tiger and armadillo ever has any chance of permanence? In the evolutionary sense, "to thine own self be true" means true to the virtues of an essentially symbiotic character coupled with cross-feeding habits, which alone avail towards life. The "mischief" which Butler says may "happen" to a species is chiefly one which follows upon disobedience to bio-moral laws. It may involve a dissolution which is apt, in one way or another, to give back the constituent parts to the common organic fund of life. It is clear, however, that species faithful to a good ancestral character, are not so to be dissolved and, therefore, not to be "assimilated" by others. Species may well be conceived as standing for a definite idea in so far as they have an

indispensable bio-economic part to play; and, in so far as this is the case, they have a special viability—much the same as good ideas have. Useful species are thus resistant to corroding influences. Their resistance is based on physical strength and on the strength of the idea for which they stand—a double-barrelled strength. The indiscriminate “assimilation,” however, of one organism by another is “abhorred by Nature.” The common prejudice, shared by Butler, that the “assimilation” of one organism by another represents the norm of life is, in my opinion, one of the most monstrous aberrations of the human mind. Instead of saying that “nothing can assimilate living organism,” I should say that living organism exists *not* to be “assimilated,” but, on the contrary, to be spared and supported *au fur et à mesure* as it is useful and its presence is desirable. That organisms must not allow themselves under various penalties to be caught napping, follows, therefore, far more rationally and consistently from a practical than from an abstract pan-psychic view. The merely abstract pan-psychic view fails to take into account the responsibilities and the “rights” of organisms, which must be fully considered in all questions of permanence. Clearly, in an evolutionary sense, “not to remember antecedents” can only mean that the organism has become untrue to an erstwhile useful bio-economic function, that it has violated the “*contrat bio-social*,” that it must consequently suffer retrogression—loss of symbiotic support with resulting loss of health and of status. The term “familiarity,” used by Butler, cannot be meant to apply to trifling matters, but must concern the most important relations of life. To cease being “familiar” with work, that is the besetting sin. We saw that the plant which fails to draw mineral salts from the earth is unable to form regular fibrous tissue of any value. It has evidently lost vital “antecedents” whilst indulging in new and non-symbiotic feeding habits. We may conclude that it is for the same reason that it will forget other important antecedents. It will gradually lose the power, for instance, of stimulating the animal for healthy work and healthy “thought,” rendering confusion worse confounded. We have seen in the case of certain wind-fertilised weeds how actual and real is the damage arising from bio-economic inferiority to the strenuous biological community. That “temptations” are a great cause of the “dislodgment” of organisms from an erstwhile high

and useful status, and that this frailty of life must be taken into account, can hardly be denied. Nor is the "dislodgment" of an organism in Nature performed by any special artifice such as we might employ in the laboratory say by cutting a particular nerve or by using a particular sleeping-draught. We know, moreover, that some organisms are more resistant than others as regards temptations. Man, for instance, cannot tempt wild animals at will into increased fertility, as recorded by Seton Thompson in the case of the blue foxes of Alaska, which are so strictly monogamous as to make it extremely hard to get a widowed fox to mate. The blue fox is evidently not inclined to be "dislodged" from sober "antecedents." It is also well-known that many plants and animals will not reproduce in domestication, even though individually vigorous; whilst others, though weak and sickly, breed freely. There remains to be written, therefore, a big chapter of Natural Philosophy anent the "nature of the organism," *i.e.*, concerning biological character.

Butler supposes that when a cross is too wide so that sterility or sterility of hybrids so produced ensues, this is due to the fact that the offspring would be "pulled hither and thither by the conflicting memories or advices"—distracted by the internal tumult of conflicting memories.

There is (he says) a fault in the chain of associated ideas.—I think (he continues) we may also expect that no other force, save that of association, should have power to kindle, so to speak, into the flame of action the atomic spark of memory, which we can alone suppose to be transmitted from one generation to another.

My comment is that before a cross can be of any real avail, a number of definite physiological and biological requirements has to be fulfilled. These requirements are mainly of the symbiotic order and, *ipso facto*, preclude a promiscuous mixing of conflicting memories. Before any association, physical or mental, can be fruitful in a real sense, can take root and status as a new form, there must exist above all the conditions for a continuance of biological service. "Conflicts," "tumults," "distractions," and "faults of associated ideas" must arise where there is a lack of reciprocal differentiation, where association unsanctioned by Nature makes *inter alia* for reproductive weakness, an instance of which we saw in the case of the Crab infested by *Sacculina*. Such weakness is really equivalent to disease, testifying to the lack of viability on the part of

non-symbiotic associations. One might, in a sense, regard the lichen as a hybrid between a fungus and an alga. This association, because of its great bio-economic usefulness, has the fullest sanction of Nature, which fact is expressed in health and in every kind of viability without any symptom of "sterility of hybrids." Everything in nature thus depends upon discriminative, *i.e.*, "right" association.

The "atomic spark of memory," spoken of by Butler, is safely supplied in Nature by symbiotic stimuli, in the case of the animal, for instance, by plant-manufactured Vitamines, which Dr. Funk, their discoverer, regards as the mother-substance of ferments and hormones, *i.e.*, the regulators of health, of growth and of reproduction.

Once the physiological connections are understood, we shall cease to over-emphasise, with Butler, the merely psychological factor, and to expect too much from a mere artificial cross. Nature cannot be supposed to be after mere crossing or mere multiplication, any more than after mere modification or mere "familiarity." Nature is after values in the widest sense of the word. The most desirable "familiarity" in Nature is that between symbiotic partners, which complement but do not devour each other, and in so doing are able to form permanent and lastingly fruitful intimacies.

A writer so conscientious as Butler does not hesitate to admit failures of theory. He would have considered it more particularly to the glory of his mnemonic theory, had it accounted satisfactorily for the difficulties presented by the problems of hybridisation which so greatly puzzled Darwin. Whilst examining Darwin's account of these difficulties, Butler concedes that his mnemonic theory appears inadequate.

This is one of Darwin's statements from *Plants and Animals under Domestication*, referred to by Butler:

Finally, we must conclude, limited though the conclusion is, that changed conditions of life have an especial power of acting injuriously on the reproductive system. The whole case is quite peculiar, for these organs, though not diseased, are thus rendered incapable of performing their proper functions, or perform them imperfectly.

This guarded statement shows the difficulties Darwin had with hybridisation—all the greater as the rationale of health and of disease was not clearly seen or defined in his day. We have seen, however, that incapacity of an organ to perform

its proper "function" or "duty" constitutes the very essence of disease. Darwin at least suspected food as making a difference, whilst Butler, failing in this instance to apply his inspiration as regards the "thoughtfulness of food," is inclined to think that the blame rests "with the inability on the part of the creature reproduced to recognise the new surroundings and, hence, with its failing to know itself," which may be quite true, so far as the mental unfitness goes, but fails to adduce the reason for it. Both Darwin and Butler, I believe, expected too much from a mere cross, as though "crosses" did not depend above all for their results on "moral signs" attached to them, *i.e.*, on the degree of their bio-economic sanction. The mysterious "factor," accounting for the reproductive weakness, for which many have searched, whether connected with food or with memory, or with one of these more than with another, is pre-eminently a bio-economic factor.

More signally still Butler's explanation breaks down in the case of hybrids "which are born well-developed and healthy, but nevertheless perfectly sterile."

Here, he thinks, it is less obvious why, having succeeded in understanding the conflicting memories of their parents, they should fail to produce offspring, and he is thus actually driven to attempt what might well be called a qualitative explanation.

"There must be," he says, "on either side a very long series of sufficiently steady memory."

The hybrid, continues Butler, may find "one single experience too small to give it the necessary faith, on the strength of which even to try to reproduce itself." In other words, there is a lack of orientation due to an "incompleteness" somewhere—probably in the relation with the environment. The case thus recalls the need in health and growth generally of a "complete diet," which need, as we have seen, has a special bio-economic significance. The idea of "mind-vitamines," possibly associated with "food-vitamines" here suggests itself. It would harmonise with Butler's contention that the organism, in order duly to know itself, must be instinct with a deep knowledge of surroundings.

Butler further thinks it probable "that all our mental powers must go through a quasi-embryological condition," which, if true, would make it appear all the more likely that Vitamines are required for mind as well as body. To say this is to assert,

in so many words, that the mind, like the body, requires to be recurrently subjected to a refining process, which is best performed whilst body and mind are in the plastic state. In that state they can best receive those subtle stimulations which we may suppose Vitamines capable of conveying which, with the concurrence of all organisms, tend to produce an effective and well-balanced biological citizen. Needless to say, the view here expressed is calculated to open up new lines of thought alike for Philosophy and for Science. For, if it be, indeed, that in the plastic state body and mind receive essential preliminary cosmo- or bio-economic "education," it follows that our minds are not so purely or exclusively human in bias as has been supposed by some thinkers. Though it be true that, as Poincaré says, "we can only think our own thoughts," yet our obligations in the matter are more profound than he assumes. And our minds are not so exclusively anthropomorphic in origin, character and aim, as a recent writer, Professor J. B. Baillie, *Hibbert Journal*, April, 1917, basing himself on Poincaré, assumes.

Butler was unable to carry the embryological analogy far enough because the full significance of Fertilisation was scarcely realised in his days. Although he is aware that Reproduction entails a strenuous business, and that if we do not improve, we grow worse, he fails to realise that such vital processes as Fertilisation and Nutrition serve quite as much as safeguards of racial and bio-economic integrity as they serve the multiplication of the species.

It must be admitted (Butler says), that when we come to consider the structures as well as the instincts of some of the neuter insects, our difficulties seem greatly increased.—Nevertheless, it must not be forgotten that bees seem to know secrets about reproduction, which utterly baffle ourselves; for example, the queen-bee appears to know how to deposit male or female eggs at will; and this is a matter of almost inconceivable sociological importance, denoting a corresponding amount of sociological and physiological knowledge generally. It should not, then, surprise us if the race should possess other secrets, whose working we are unable to follow, or even detect at all.

Finally he gets over his difficulty by saying that structure and instinct are alike due, if not to mere memory, then, at any rate, to "medicined" memory. He discerns at last that memory requires appropriate food—symbiotic food, as is so well borne out by the case of the bee. I have elsewhere pointed out that the notorious ill-effects of felonious honey-getting upon

the bee are typical of the *misère* attending the non-reciprocal life generally, though the symptoms be not always as pronounced as they are in this case. That Butler saw the same sequence much in the same light as I do, at least in the case of the bee, follows from what he says on page 240, namely, that owing to temptations bees may quit their "grave, prudent and mercantile character" and become "exceedingly profligate and debauched," eating up instead of saving their capital, resolved to work no more.

According to the bio-economic view, we have here a distorted and incomplete Symbiosis, leading, by way of reaction, to incompleteness in the physical and mental equipment of the bee. The case is typical of the way in which transgression against bio-economic law in the end produces diminution, or stoppage, of essential supplies with resulting degenerative effects upon structure. It is possible that in their normal state the bees know how to "handle" the Vitamines and other subtle ingredients of the food, such as are ever at the command of the symbiotic cross-feeder. And this would indeed constitute, in Butler's words, a matter of "almost inconceivable sociological importance" so far as the bees' commonwealth and their business in life are concerned. Obviously, moreover, the "knowledge" of the bee includes the understanding of an adequate limitation of reproduction in accordance with bio-economic contingencies. Doubtless, the secret of the portentous "knowledge" of the bee lies in Symbiosis, which, as we have seen, precisely provides "well-connected" and "well-inspired" knowledge. "Complete memory," "complete inheritance," "complete diet," and "complete Symbiosis," thus go together.

It is clear, however, that Butler felt obliged to circumnavigate the subject of food and feeding. As I have stated above, it was not given to him to raise the study of food to the platform of Bio-Economics. He confined himself instead to pointing out the portentous importance of the subject and throwing out valuable suggestions as to how the difficulties might one day be solved. With his usual candour he makes further admissions of failure, as when he says:

I grant, however, that it is hard to see how change of food and treatment can puzzle an insect into such "complex growth" as that it should make a cavity in its thigh, grow an invaluable proboscis and betray a practical knowledge of difficult mathematical problems.

But the resources of Nature are equal to such tasks. Butler was not one, however, long to remain *felix errore suo*. With the aid of fresh inspirations, he makes further suggestions approaching the symbio-psychic view and visualising the quasi-genetic value of food.

This is what he says :

The line, again, might certainly be taken that the difference in structure and instincts between neuter and fertile bees is due to the specific effects of certain food and treatment ; yet, *though one would be sorry to set limits to the convertibility of food and genius*, it seems hard to believe that there can be any untutored food which should teach a bee to make a hexagonal cell as soon as it was born, or which, before it was born, should teach it to prepare such structures as it would require in after life. If, then, *food be considered as a direct agent* in causing the structure and instinct, and not an indirect agent, merely indicating to the larva that it is to make itself after the fashion of neuter bees, then we should bear in mind, at any rate, it has been leavened and prepared in the stomachs of those neuter bees into which the larva is now expected to develop itself, and may thus have in it more true germinative matter—gemmules, in fact—than is commonly supposed. *Food, when sufficiently assimilated* (the whole question turning upon what is "sufficiently") becomes stored with all the experience and memories of the assimilating creature ; corn becomes hen, and knows nothing but hen, when hen has eaten it. (Italics mine.)

All that is necessary to harmonise these highly suggestive views with Bio-Economics and to overcome at the same time the discrepancies so keenly felt by their author, is to allow that the chief and prime "tutoring" of the food takes place at the hands of symbiotic nature. Butler overlooks the fact which is not without pan-psychic importance, that the bee is a symbiotic cross-feeder, in virtue of which it receives specially prepared surplus capital from a partner, from one who, as a result of primordial symbiotic intimacy, has a sense of awareness concerning the needs of the bees and is ideally fitted to supply these needs. It is quite probable that the neuter bees "know" how to supplement the natural "tutoring" of the food by some further elaboration, in accordance with special circumstances. Given a good fundamental biological orientation, however unconscious, it should not be difficult for either partner in Symbiosis to make further progressive recognitions of social and bio-social importance. The "maturation" of the food is commenced by the symbiotic plant. It may be carried a step further by the animal for special purposes. And thus, in the place

of Butler's "convertibility of food and genius," we get, more soberly and more consistently with the hypothesis of evolution, and even with pan-psychism itself, co-operation between animal and plant and mutual elevation by work—food being an important medium of mutual stimulation. Instead of making the relatively katabolic organism, the animal, perform the chief endowing of the food, Butler should have made the relatively anabolic organism, the plant, responsible for the chief endowment of the food.

It is quite evident, particularly from the last sentences in Butler's suggestive passage, that there had to be a deadlock in his mnemonic theory, as indeed in any other theory of evolution, pending the elucidation of the problem of "digestive transformation," than which there is scarcely one more important. The difference of point of view between the one adopted by Butler and that which I commend, is all-important. It is as one between Nihilism on the one hand, and "Co-operation and Government" on the other.

The whole matter is so important that a digression on the subject will not be out of place. Butler, in common with other writers, shows himself a "Nihilist" in so far as he assumes that "devouring" and complete "assimilation" of one organism by another produces the good effects, which are really due to Symbiosis. The animal, according to the "nihilistic" view, has a genius peculiar to itself, and, in devouring the plant, or the corn, "dislodges" and "annihilates" the plant genius, "converting," or "assimilating" it at the same time. But the case does not stand quite so nihilistically, and there is far more co-equality of genius and also of service between plant and animal than we are led by him to suppose. The contribution of the plant to animal endowment, which is of course very considerable, is by no means a one-sided and arbitrary business, based, as it is commonly thought, upon depredation. It is rather one of mutual penetration—the best balance being struck when "corn" becomes as much "hen" as "hen" becomes "corn"; the resulting mutual "understanding" being essential to, and collectively benefiting, the welfare of plant and animal kingdoms.

We have quite recently obtained some light as regards the mechanism of "digestive transformation" characteristic of animal life. In the main what information has been gained, tends to confirm my generalisation concerning the superiority of cross-over in-feeding and to corroborate my contention concerning the

wholesome, energising, regulating and restraining rôle played by symbiotic food. Just as in the case of plant nutrition, treated of in the second chapter, so as regards animal nutrition, we have learnt that it is the simple materials which chiefly count. Though we use proteins for instance, it is their constituents, the amino-acids, which are really wanted. These are the indispensable "building-stones" in animal nutrition and they are for the most part manufactured by the plant. They are produced not only for the support of the plant's own offspring, but also for the purpose of "export," *i.e.*, the support of the animal as the biological partner of the plant.

From a paper on *The Bio-chemical Analysis of Nutrition*, by C. L. Alsberg (U. S. Bureau of Chemistry) in the *Scientific American*, Supplement, 24th March, 1917, we gather the following: In Liebig's time proteins were regarded as that element of the food which supplied the material for growth, tissue maintenance and repair, as well as for most of the energy. It was however soon demonstrated that while proteins did and could furnish energy, under ordinary conditions this was supplied in the main by sugar and other carbo-hydrates and by catabolised fats [*i.e.*, the materials chiefly drawn from cross-feeding]. For long it was held that one protein was of about as much dietary value as another, which, however, was found to be an erroneous notion. Then a startling discovery published in 1901, by Loewi tended to show that it was not absolutely necessary to life that protein be an element of the diet at all. What is really indispensable is a suitable mixture of "building stones," *i.e.*, amino-acids—ordinary organic acids in which one or two hydrogen atoms have been replaced by the amino group NH_2 . The proteins are combinations of a number of these amino-acids with one another. It should be theoretically possible, says Dr. Alsberg, to supply the "so-called" protein needs of animals by wholly artificial substances, such as the seventeen or eighteen pure crystalline amino-acids that we knew of. [This I venture to interpret as meaning that normally the animal can well be fed by the surplus "building stones" of the plant.]

On the matter of the "conversion" of proteins by means of digestion, it will be best to quote Dr. Alsberg in extenso: This is what he states:

Whatever may be the ultimate practical significance of the observations that animals can supply themselves with most or all of their nitrogen

needs by means of synthetic amino-acids, these experiments have led to investigations that have explained much that has been obscure in the physiology of nutrition. Formerly it was believed that proteins when ingested were digested by the enzymes of the intestinal tract and converted into simpler substances in the main albumoses and peptones, which were absorbed. These albumoses and peptones, while simpler than most food proteins, are nevertheless, still very complex substances. It was believed that they are absorbed *and then converted by the animal into the protein characteristic of that particular animal*. How that conversion was accomplished was not understood. Now every species of animal and plant has its own characteristic proteins. The proteins of *even closely related species are different*. *The proteins of the food supply are quite different from those of the animal taking that food*. Much work was done to explain how the proteins of the food were converted into proteins of the body and where this conversion took place. At first it was believed to occur in the blood. Later a difference of opinion arose as to whether it took place in the tissues or in the intestinal wall. As food proteins could be demonstrated in neither place, the matter remained unsettled. We know to-day that neither hypothesis is tenable. *Proteins are not ordinarily absorbed as such*. They are completely dismembered within the intestinal canal into their component *amino-acids and these are absorbed*. As long as it was not known that an animal can be maintained upon pure synthetic amino-acids, no one had any reason to believe that proteins were completely digested before absorption. (Italics mine.)

These explanations should do away with the theory propounded in all seriousness by some writers that the most ideal food is that obtainable through in-feeding, and that in the case of man, for instance, the ideal diet would be human flesh. It should do away with the more widely held absurdity that one organism inevitably needs to kill, to absorb, and to "assimilate" another in order to satisfy its real food needs. The fact that proteins are completely digested, *i.e.*, broken up before absorption, moreover, is not only interesting in connection with the fact that an animal can be maintained upon pure synthetic amino-acids. It also shows, in my opinion, that highly complex proteins are not really wanted as food. True, it is part of the function of the digestive tract to get rid of impurities and non-congenial substances. But we must not abuse our digestive and eliminative powers by food that is too rich, *i.e.*, too complex. The best materials that our diet can ever furnish are the "building stones" coming originally from the plant, and these make no undue claims on digestion and elimination. The really vital and abiding union sought after in animal nutrition, is between the amino-acids of the plant and the blood of the animal. It is in conformity with the principle of reciprocity or reciprocal differentiation that we want in our diet "quite different proteins"

to those forming our own bodies. We want in fact symbiotic cross-food or spare-food capital, which contains the vital amino-acids fit for reciprocity in ideal association with other indispensable "export" material of the plant. It is partly because of our long-standing transgression against the norm of feeding that we are provided with the cumber of a long digestive tract, which serves the secondary purpose of separating the useful from the unnecessary in our diets.

Elimination and the further fate of the absorbed amino-acids is thus described by Dr. Alsberg:

As ordinary diet may contain more nitrogenous material than is needed by the organism, a part of the amino-acids is changed within the walls of the intestinal canal by the removal of the amino-group to form ammonia. As this takes place in the presence of carbonic acid, ammonium carbonate and ammonium carbamate are formed. It has recently been found that there is an equilibrium between these two substances, so that where one is present in solution there is also found a definite amount of the other. It is an easy step from ammonium carbamate to urea. Thus the amino-group split off from the amino-acid in the intestinal wall or elsewhere is ultimately converted into urea and excreted. There are probably other methods of the formation of urea, as, for example, by cleavage from arginine which contains a guanidine grouping closely related to urea. After the removal of the amino-group from the amino-acids there is left a carbonaceous residue which may be burned to furnish energy, perhaps directly, perhaps after conversion into sugar. A portion of the amino-acids absorbed by the intestines is not, however, deprived of its nitrogen, [it is only the "too much nitrogen" that we are to be safeguarded against as long as possible], but passes into the blood stream from which it is absorbed by each individual cell according to that cell's particular needs. [Real or pathological needs, I should, however, add, for it is a notorious fact that as Emerson has stated, we breed men with too much "guano" in their composition, which is saying in other words that many cells have developed exorbitant nitrogen appetites.] The cell then reconstructs from these amino-acids its own characteristic protein. [The reduction process being accomplished with more or less efficiency, the animal cell at last obtains a modest portion of indispensable "cross-food" and can now, thus impregnated, "generate" its own characteristic, yet in a sense "heterozygous" proteins. "Crossing," in the wider sense, is thus again seen to contain a secret of evolution.] Thus it is possible to explain in a comparatively simple manner how, for example, wheat protein [cross-food] when fed to an animal is converted into the characteristic protein of that animal. It is done by the cells of the tissues from amino-acids supplied to the cells by the blood, the blood receiving the amino-acids from the intestinal wall.

I should say, however, that the animal receives the amino-acids from the laboratory of the plant by reason of the

Symbiosis existing between plant and animal. Their ultimate conversion by the blood and the tissues traced by modern science represents but a final phase of the real Bio-chemistry of food.

It is not "wheat," therefore, or "corn," that become "hen" in the sense that the individualities of the herbs find their consummation by being taken up into that of "hen." It is only the amino-acids manufactured by these herbs in their bio-chemical laboratory for "export" that go to form the characteristic proteins of the "hen," yielding all the while to the latter a number of indispensable good influences, which go to "convert" the animal, so far as its character and its "psyche" are concerned, quite as much as the amino-acids of the plant are eventually converted into the characteristic protein of the animal. It is a case of the digestive transformation of special substances in the ordinary course of Symbiosis—far from inevitably necessitating the devouring of producer by consumer.

The animal, Dr. Alsberg tells us, is incapable of manufacturing for itself certain amino-acids [which it yet requires]. The plant, however, is capable of making all the amino-acids necessary to support its own life [and, I should add, enough to spare]. Whether or not an animal can build up its own tissue protein depends upon the supply of amino-acids. Failing these, it suffers a kind of starvation.

The importance of other influences conveyed by symbiotic food may be seen from the further fact communicated by Dr. Alsberg to the effect that lime juice, for instance, which is a valuable anti-scorbutic, contains unusually stable Vitamines: "It has been suggested" he says, "that the free organic acid present in the lime juice protects the anti-scorbutic substances."

Evidently the most ideal substances for animal diet and the most ideal blends of substances are to be found amongst the spare foods of plants, which foods are distinguished from the "untutored" food spoken of by Butler in that they are derived from an adequate symbiotic relation between supplier and supplied. "Untutored" food, in the sense of lacking such essential bio-economic qualification, *i.e.*, special preparation and maturation by a willing partner, is unsuitable food—apt to be the cause of disease and of a morbid Pan-Psychism.

Butler, as the champion of Lamarck, whose leading ideas, according to him, had been much used though with anything but

due acknowledgment, took exception to the following, oft-quoted passage from the *Origin* :

In the case of the mistletoe, which draws its nourishment from certain trees, which has seeds that must be transported by certain birds and which has flowers with separate sexes absolutely requiring the agency of certain insects to bring pollen from one flower to another, it is equally preposterous to account for the structure of this parasite with its relations to several distinct organic beings by the effect of external conditions, or of habit, or of the volition of the plant itself.

Certainly it would not do to account for this case with any one of these factors alone. We require an explanation that does justice to all the factors. The question, however, is, to which of these factors we are to assign chief importance. In my opinion, it is to "sociological" or bio-economic factors—standing out prominently even in Darwin's account—that the chief importance is due.

Butler protests that Darwin makes the case of the mistletoe look more formidable than it really is. Yet, it is clear that he himself cannot here fully meet the difficulty. He says this :

Neither plant nor bird knew how far they were going or saw more than a very little ahead as to the means of remedying this or that with which they were dissatisfied, or of getting this or that which they desired ; but given perceptions at all, and a sense of needs and of the gratification of those needs, and thus hope and fear, and a sense of content and discontent—given also that some individuals have those powers in a higher degree than others—given also continued personality and memory over a vast extent of time—and the whole phenomena of species and genera resolve themselves into an illustration of the old proverb, that what is one man's meat is another man's poison.

A critic might justly say that this explanation is too purely psychological, that it fails to do justice to the biological (bio-social) factor, and that the answer that "what is one man's meat is another man's poison" provides too superficial an account of the diversification of species and genera with their manifold and important correlations. This proverb furnishes far too bald a statement of the biological law, which, according to Butler's own subsequent inspirations, involves a number of bio- or quasi-moral obligations on the part of the organism. The bald explanation merely slurs over inter-connectedness. It may be true in a sense, in the case of the mistletoe, that plant and bird (and cross-fertilising insect) each and all merely stumbled upon their special relation, which yet proved of great mutual

benefit. But it must be borne in mind that similar inter-connectedness has always been the law of their being, and that their special inter-connectedness, therefore, is by no means so casual a matter as at first glance it looks. The special case of the mistletoe merely consists in this: that we have here a partial loss of the symbiotic sense, a retrogression from an erstwhile purely symbiotic relation, inasmuch as the plant draws non-reciprocally on another organism, namely the tree. The mistletoe presents an instance of a striking concomitance of a parasitic with a symbiotic relation and of corresponding anomalies of structure. It is this concomitance which introduces the complexity and which is responsible for the difficulties of interpretation which baffled Darwin and many others.

In the case of bio-economic retrogression, a kind of imbrigliolo is sure to arise in the constitution of the organism. The components introduced by degenerative tendencies become variously blended with, and superposed upon, the components of health. The result may be a very heterogeneous mixture, a condominium of components—good and bad, ancient and modern. It may be said that the very capacity for progress acquired painfully during millenniums of symbiotic evolution, may come to be employed by the organism retrogressively in accordance with a lazy compliance with low conditions rather than in accordance with progressive efforts. I consider the case of the mistletoe to be one of this kind—a case of partly disintegrated symbiotic integrity. The mistletoe has by no means descended to the depth of a rank parasite. The fact of the green colouration of its leaves alone shows that this plant is not entirely devoid of wholesome bio-economic activities. How are Biologists to distinguish what is due to Symbiosis in an organism from what is due to parasitic influences? The reading of the respective symptoms will be done by each according to his abilities of diagnosing Health and Disease, according to the distinctions he is wont to draw as regards values generally. So long as in the absence of agreement as to "values," we have no definite biological analysis, the case of the mistletoe of course, must remain perplexing.

The need of tackling anew the problem of Variation in this connection, has caused Butler to expand his "Mnemo-Lamarckism" into an interpretation more specifically sociological, and hence more satisfactory, than his previous view to the effect that the saying that "what is one man's meat is another man's

poison " provides the best key to an understanding of " modification " and species-formation. Variations, he says, are probably less blind than we think, " if we could know the whole truth," and he proceeds to connect the trend of variations with the gradual growth of " organic wealth " through work. Limbs or instincts, all alike, he would but regard as the things that organisms " have bought with their money, or with money that has been left them by their forefathers, which, though it is neither silver, nor gold, but faith and protoplasm only, is good money and capital notwithstanding."

Butler does not think that the desire of the organism is the sole cause of variations, but, in a passage which may be regarded as an attempt at a blend of Lamarckism with Darwinism, he suggests that there is a mutual determination of some sort between organism and "environment." He admits readily that

The common course of nature would both cause many variations to arise independently of any desire on the part of the animal—and would also preserve and accumulate such variations when they had arisen. But (he goes on to say), I can no more believe that the wonderful adaptation of structure to needs, which we see around us in such an infinite number of plants and animals, can have arisen without a perception of those needs on the part of the creature in whom the structure appears, than I can believe that the form of the dray-horse or greyhound—so well adapted both to the needs of the animal in his daily service to man and to the desires of man, that the creature should do him this daily service—can have arisen without any desire on man's part to produce this particular structure, or without the inherited habit of performing the corresponding actions for man, on the part of the greyhound and dray-horse.

There is then something of importance attributable to the "common course of nature"—whatever this course may be. This something operates over and above volition, over and above memory although it is not unconnected with either. I think it is now evident that Symbiosis with its momenta provides the best clue to an understanding of the mysterious influence, not dissociable from volition and memory, yet inherent in the "common course of nature." It is in Symbiogenesis that I believe we have an explanation of the way in which the tendencies of the organism are being made use of in the preservation and accumulation of variations in accordance with their merits. We can believe this without having in any way to deny the concurrence of mind and of volition on the part of the organism. How otherwise puzzling the subject of variations remains may best be seen from a

statement by Geddes and Thomson in their little work on *Evolution* (pp. 141, 142). They tell us that it is quite impossible at present to say how variations arise.

We know very little, they say, that is certain in regard to the originating factors in evolution. We must still confess, with Darwin: "Our ignorance of the laws of variation is profound."

Weismann has suggested that the oscillations and changes in the blood and other nutritive fluids may stimulate the germ-plasm to a new departure. It may also be that important changes in the environment may saturate through the body and provoke the germ-plasm to vary. There are other "may be's."

The suggestions thus thrown out are not antagonistic to the symbiogenetic view. It is only necessary to realise the quasi-genetic value of food and its rôle as mediator between organism and the environment in order to understand how the symbiogenetic and symbio-psychic complex of life produces an urge consistent only with the highest good of the organic world, which urge is enough to call forth and to direct variations as required in the normal course of life.

After telling us that Lamarck's theory fell into disrepute, partly because his ideas were too startling to be capable of ready fusion with existing ideas, Butler asserts that the main cause of evolution must be looked for, as Lamarck insisted, in the needs and experiences of the creatures varying, and in this connection he attacks once more the problem of Variation thus:

Unless we can explain the origin of variations, we are met by the unexpected at every step in the progress of a creature from its original homogeneous condition to its differentiation, we will say, as an elephant; so that to say that an elephant has become an elephant through the accumulation of vast numbers of small, fortuitous, but unexplained, variations in some lower creatures, is really to say that it has become an elephant owing to a series of causes about which we know nothing whatever, or, in other words, that one does not know how it came to be an elephant. But to say that an elephant has become an elephant owing to a series of variations, nine-tenths of which were caused by the wishes of the creature, or creatures from which the elephant is descended—this is to offer a reason, and definitely put the insoluble one step further back.

A good beginning towards explaining the origin of variations is undoubtedly made by pointing to the volition of the original creature. But it is only a beginning, and it does not go far enough.

It is well to go back for a clue to the "original creature"; but the volition and interests of one organism are constantly

met by those of others, and there is, therefore, a perennial need of harmonious mutual accommodation and a commensurate eternal obligation of good biological conduct—all progressive evolution being in accordance with such conduct.

Variations may be viewed as procreations owing everything to biological support and dependent in turn upon biological, *i.e.*, bio-social sanction. The elephant, no doubt, is a "mighty" creature. It must have had a very viable protoplasm to start with, as indeed we should expect in the case of a cross-feeder. It is possible that it is the yearning of every species to become mighty, to replenish and inherit the earth. Such yearning, however, is futile if the commensurate fundamental conditions have not first been supplied through adequate cross-feeding and adequate Symbiosis. This is the great law of which Butler evidently had a presentiment. Seeing how great is the number of species that have failed and that the elephant itself is a failure, in as much as it verges as a species on senescence, I would correct Butler by the addendum that the norm of variations is due to "healthy" volition. The elephant, though a cross-feeder, has yet become highly predaceous and destructive *vis-à-vis* to plant-life, and has therefore failed to make right symbiotic use of its powers. The eventual attainment of monstrous size by this species, therefore, is a poor achievement of "appetency." In my opinion it has been attained somewhat pathologically. Malformation and monstrosity may arise simply from absence of certain essential ingredients of the food. I consider monstrosity of species to be due to a gradual evolutionary form of giant's disease, a fact upon which I have insisted in all my writings. The plant yields a "complete diet" only to those animals which are restrained and industrious in their habits and treat it with symbiotic forbearance. Predaceous animals must be satisfied with what I believe is inferior pabulum, which may be the cause of disease.

Butler's suggestion, therefore, that nine variations out of ten are due to "appetency" is an exaggeration; or at any rate it needs the qualification that only healthy wishes can be fruitful. We get, however, once more, from Butler the important recognition that there are "good" ways and "bad" ways of living, it being left to the reader's judgment to supply the necessary distinctions and criteria. We are told: "An animal which discovers the good way will gradually develop further

powers, and so species will get further and further apart." The "bad" so we are left to infer, are left behind or eliminated. In the place of Darwin's statement that although he (Darwin) sees no good evidence of the existence in organic beings of a tendency towards progressive development, yet this necessarily follows through the continued action of natural selection, Butler will have it simply that plants and animals have only an innate power to vary slightly in accordance with changed conditions. Butler further says that they have an innate capability of being affected both in structure and instinct, by causes similar to those which we observe to affect ourselves. The case of Lamarckian "appetency" is put more forcibly still in the following passage, which may be said to foreshadow the coming of a theory of conduct pure and simple :

One neither finds nor expects much *a priori* knowledge, whether in man or beast ; but one does find some little in the beginnings of, and throughout the development of, every habit, at the commencement of which, and on every successive improvement in which, deductive and inductive methods are, as it were, fused. Thus the effect where we can best watch its causes, seems mainly produced by a desire for a definite object—in some cases a serious and sensible desire, in others an idle one, in others again, a mistaken one ; and sometimes by a blunder which, in the hands of an otherwise able creature, has turned up trumps. In wild animals and plants the divergences have been accumulated, if they answered to the prolonged desires of the creature itself, and if these desires were to its true ultimate good ; with plants or animals under domestication they have been accumulated if they answered a little to the original wishes of the creature, and much to the wishes of man. As long as man continued to like them, they would be advantageous to the creature ; when he tired of them, they would be disadvantageous to it, and would accumulate no longer. Surely the results produced in the adaptation of structure to need among many plants and insects are better accounted for on this, which I suppose to be Lamarck's view, namely, by supposing that what goes on amongst ourselves has gone on amongst all creatures, than by supposing that these adaptations are the results of perfectly blind and unintelligent variations.

What emerges is this : the accumulation of variations is according to "values" rather than "wishes." The clause "if these desires were to its ultimate good" gives away the case for mere "wishes." Moreover, if, by hypothesis, we are to credit creatures with little *a priori* knowledge, we could scarcely credit them with profound enough wishes to procure the great end of their "true ultimate good." Something bigger than mere wishing is wanted to obtain this. And this something, I contend.

is the co-operative urge of things. It is Symbiogenesis, more precisely, that directs the long protracted gestation processes of Nature and thereby also determines the preservation of the most widely useful variations.

Butler saw that Domestication presents a narrower, more casual, arbitrary and lopsided biological relation than is presented by the case of species under Nature. Evidently creatures or races obliged to submit too exclusively and too one-sidedly to the desires and whims of others, lose thereby the power of determining their own good. Too occupied with merely expedient necessities, they are virtually slaves. Slavery cannot breed healthy wishes in master or slave ; and for this reason alone it could never obtain the sanction of Nature. Hence it is that in the past all civilisations, organic or human, based upon the principle of slavery, have ended in failure. Just as Nature abhors perpetual in-breeding, and I believe also perpetual in-feeding, so I believe she "abhors" slavery. The reason is the same in every case : What is really wanted is the maintenance of bio-economic integrity, independence of every species though in due inter-dependence with others—the very antithesis of slavery. The conclusion is that the evolution of life is indispensably connected with Bio-Economics and Bio-Morality.

PART II

CHAPTER I

“NORMALS”

DR. J. S. HALDANE and other eminent physiologists have insisted that recent study of “normals,” *i.e.*, the persistent and constant behaviour shown by the parts of the body in all important life-functions, makes for an entirely new interpretation of Physiology. Dr. Haldane tells us that physiological study and biological study generally seem to make it clear that throughout all the detail of physiological reaction and anatomical structure we can discern the maintenance of an articulated or organised normal. There is, for example, as he points out, an almost incredible constancy in the composition of the blood, and there are similar constants or normals with regard to our body temperature and with regard to respiration and nutrition. Were it not for these normals, Dr. Haldane tells us, the reactions of the cells would become chaotic, and their structure would be completely altered if not destroyed. Living organisms, according to Dr. Haldane, seek to meet all disturbances imposed upon them in such a way as to maintain the “normal” in essential points. Wherever we look we find “normals” to which return is made with surprising persistence and accuracy. By “normal” is meant “not what is average, but what is normal *in the biological sense* (*italics mine*). Dr. Haldane speaks of the condition in which the organism is maintaining in integrity all the inter-connected “normals” which manifest themselves in both bodily structure and activity. The “normals” indeed, he avers, are the expression of what the organism is.

Now, in my opinion, the study of “normals,” especially when duly expanded to comprise “causes,” is of almost inconceivable importance, as I hope to have to some extent shown by my repeated demonstration of the “normal” of feeding and of its importance in determining normal, *i.e.*, physiological growth and normal or physiological evolution, as distinguished

from abnormal or pathological growth and evolution. Such study is apt to reveal not only a few diagnostically interesting data, but, what is more, it reveals the fundamental Economy of Nature, with its demand for definite duty, definite constitution, and definite integrity, a demand made on all participants in the cosmic scheme, organic or inorganic, in the interest of all. The "normals" may thus be viewed as an expression of the requirements of mutual accommodation of all systems in the cosmos. Biological "normals" in especial may be viewed as connected with biological accommodation, past and present, of the organism.

Let us take as an example the "normals" of respiration and of feeding. So far as respiration and nutrition are concerned, as is well known, plant and animal to a certain extent mutually complement each other. It is a case of past mutual evolution, of simple and collective Symbiosis. Without the symbiotic share of the plant and without adequate degrees of symbiotic reaction on the part of the animal, the normals of respiration and of nutrition existing in the physiological economy of the animal could never have been evolved or maintained. I go further and declare that without Symbiosis nothing but chaotic action and reaction could have taken place. We have seen that but for the restraints entailed by the symbiotic *régime*, the conduct and the feeding methods of organisms are apt to become chaotic, whilst the organism itself becomes debauched and tends towards monstrosity and general abnormality.

The breathing, so Dr. Haldane tells us, "is more or less regulated to correspond with the consumption of oxygen and the production of carbon dioxide in the body." It is thus obvious that the "normal" of respiration is intimately connected with work, with the general biological activities and the biological relations of the animal. Symbiosis, as we have seen, implies systematic and constant though modest and wholesome activity, which means regular and wholesome exercise for the lungs, thus enabling them to regulate breathing in an economical manner. It is also evident that the supply of carbo-hydrates by the symbiotic plant must largely determine the carbon dioxide production of the animal. The capacity of the plant to supply carbo-hydrates depends in turn upon the treatment and the general support it receives from the animal as the biological

partner. The important fact of such partnership, however, is generally overlooked.

An example of the way in which Symbiosis is under-estimated even by the most broad-minded of Biologists may be gleaned from Dr. H. F. Osborn's recent essays on *The Origin of Evolution and of Life*. He admits that plants establish a marvellous series of life environment interactions, but says that this is done first with the developing insect life, and "finally" with the developing bird life. It must be clear by now that these interactions by no means cease with birds. They embrace all the highest types of life as well, and, the higher we ascend in the evolutionary scale, the more vitally important they become. The development of the mammals, for instance, would have been quite impossible without an adequate supply of Vitamines. What supplies these Vitamines? The plant. The plant alone (though in many ways symbiotically supported by the animal) is capable of manufacturing Vitamines.

I would point out, moreover, that it is not only amongst birds but more particularly amongst mammals that adaptation to a fruit diet has reached striking degrees of perfection, which shows that Symbiosis with plant life represents the norm of animal life.

CHAPTER II

LA VIE NORMALE

LONG before I began writing on "Evolution" I had satisfied myself by years of observation that there existed amongst organisms, including man, a vast amount of pathological development connected with change of form, with outgrowths and excrescences of all kinds, and, particularly with abnormal or "teratological" increase of size, affecting not only single organs or individuals, but in the end even whole groups, species and genera, and diminishing their chances of life.

Naturally I sought for the cause of the phenomenon. As a medical student, it struck me that it would be of the utmost importance if an inquiry into these matters were to bring out—as I believe it has brought out—the exact separating lines between Physiology and Pathology.

As a result of many years of investigation and after carefully checking and counter-checking my results, I have arrived at the conclusion that the general cause of pathological change of form is ill-feeding and a consequent diathesis—a predisposition to a well-marked pathological process. It remained to be seen, however, why some feeding habits, more than others, produce pathological increase of size,—augmenting with a kind of arithmetical progression with every succeeding generation. There was moreover the geological fact, that side by side with the monsters there had remained those types—a kind of normal kin—which have not undergone a startling increase of size nor developed a tendency to disease and early senescence. What kind of good fortune, of virtue or integrity, has been theirs to differentiate them so favourably from the monsters? My analysis has brought out the fact that the normal kin are those which have remained tolerably faithful to a mode of feeding which is bio-economically sound, entailing forbearance with life, *i.e.*, the live-and-let-live principle such as that governing the relations between partners in Symbiosis. The normal organism, in fact, is that which is a symbiotic cross-feeder, though it be not physically attached to the biological partner. The

verdict of geological history in these matters is this, that constitution, health and form of organisms are pre-eminently determined by bio-economic factors, demanding above all reciprocity and moderation from all forms of life. The evidence of the rocks, re-inforced by clinical experience, bears witness to the fact that there is a normal life, *i.e.*, one characterised by normal industry, normal nutrition and normal form. These conjoint normals I have found owe their existence to a normal, *i.e.*, mainly co-operative or symbiotic relation as between organism and biological community at large. The non-symbiotic relation, on the other hand, being apt to lead to unrestrained and unredemptive self-indulgence, easily tends to pervert and to undermine those "normals" with the result of comparatively licentious growth. The organism lives for self rather than for the common good. What it gains on the one hand, it loses, however, on the other. That is to say, its gains of size are at the expense of biological support and sanction and of survival-capacity. Here then we have the dividing line between physiological and pathological development. In my books on *Nutrition and Evolution* and *Survival and Reproduction* I have treated of teratology and monstrosity, and of sexual dimorphism (antithesis of size) from the same point of view as here set forth. The subject is dealt with more particularly from the medical point of view in my little work on *Evolution by Co-operation* (1913), where special references may be seen on pages 6, 64-6, 69, 77-79, 171, 186-7. On page 66 of that book, moreover, attention is specially called to the deterioration of character as a concomitant of the acromegalic diathesis. As instances of pathological increase of size in Nature, I have mentioned the dinosauria, the living and extinct monstrous birds, the whales and elephants, the monstrous insects and monstrous plants. I have also tried to show that the more intense the degree of "in-feeding," or of depredation on the part of a species, the more pronounced is the (parasitic) diathesis and the resulting monstrosity.

I have further demonstrated (p. 79) that inversely, with a return to a more symbiotic mode of life, *i.e.*, with a re-conversion from in- to cross-feeding, the diathesis may be reduced, the organism returning to a more normal condition of size. The acromegalic diathesis, however, is hereditary, and, though a cure by reconversion be possible, in the majority of cases found

in Nature, the acromegalic organism is past praying for, *i.e.*, the diathesis has too far progressed for cure. In my paper before the British Association, Section I., 1912, I pointed out that "in-feeding" and the ensuing metabolic abnormality are the causes of antithetic and teratological developments, of sexual dimorphism, female preponderance in parthenogenesis, and of those phenomena of increase of size during palæontological periods which Cope's law takes into account.

Unfortunately the reviewing of my books in *Nature* is generally done with others *en bloc*. Mr. A. E. Crawley, to whose lot it fell to report on *Evolution by Co-operation* (19th March, 1914) in company with five other volumes, merely contented himself (in a quite sympathetic report) with the statement that my book contained "interesting observations on the fallacy of in-feeding, which is parallel to in-breeding."

Now, however, according to a full-dress review in *Nature*, 19th July, 1917, by Professor A. Keith, another writer, Dr. René Larger, has come forward with a theory of *contre-évolution*, purporting to show that

Gigantism and acromegaly may attack not an individual here and there as among mankind, but may break out in a whole species or genus, so that all the individuals become affected, at first with a moderate degree of acromegaly, but finally with an unrestrained pitch of gigantism, in which condition the whole race or family finally perishes. He is of opinion (the reviewer continues), that this theory explains many facts, which now seem obscure to those who are studying living and extinct forms of animal life. He selects his examples from the great dinosaurians, the living and extinct great birds, and whales, elephants and anthropoids as mammalian representatives.

Dr. Larger apparently connects the pathology in the case of animals (to which it is by no means confined) with a disordered state of the glands of the body, in particular the pituitary gland.

Whilst claiming priority for the application of a comprehensive pathological theory to the extinction of species, I welcome Dr. Larger's version as a kindred theory to mine, though one that does not seem to go far enough into the true causes of the disease. I hope that his work will help to call attention to "Evolutional Pathology," a chapter of Evolution which I have never tired of stressing as of the utmost importance. I have no fault to find with Dr. Larger, who seems to have developed his theory quite independently of my writings. I could wish, however, that my principal theses had not been slurred over in scientific reviews.

where a little information about the contents of the books would have been appropriate. I would further point out that, as a scientific thinker, I cannot countenance the view that a species has been "attacked" by a disease, leaving the matter at that. I hold that every effect, physiological or biological, good or bad, has had a commensurate cause, and, hence, that a disease so serious as acromegaly must originate in some serious transgression against natural law. This, I know, is a novel and therefore strange point of view, but one, nevertheless, which must prevail.

We have seen that function rests on "duty" and that even the so-called "physiological economy" of the body is governed by strict laws of biological co-operation. The activity of the glands in particular depends primarily upon food—which either makes or mars the organism in accordance with the biological equity of its food-getting. To see that this is so, requires nothing more than a quite legitimate expansion of the principle of cause and effect to the subjects of physiological and biological "economy."

Having reluctantly said so much *pro domo*, I would once more emphasise the fact that the normal and ideal life is never the life of indulgence. This truth may be said to be the biological counterpart of the Christian teaching that it is easier for a camel to go through the eye of a needle than for a rich man to enter into Heaven.

The rich man is the most apt to be tempted to self-indulgence which leads to physical and mental perversions detrimental to ultimate survival. And this is also why the *vox populi* may at times be worth listening to. It may, and frequently does, represent the wisdom of "la vie normale" and as such proves a valuable corrective of "acromegalic" tendencies in politics, etc. We can thus better understand Ruskin, whose paramount teaching was that the increase of both honour and beauty is habitually on the side of restraint, declaring that

Out of the peat-cottage come faith, courage, self-sacrifice, purity and piety, and whatever else is fruitful in the work of Heaven; out of the ivory palace come treachery, cruelty, cowardice, idolatry, bestiality—whatever else is fruitful in the work of Hell.

It has been said that the fat man knoweth not what the lean man thinketh; and if, as is evident from history and from biology, a kind of diathesis may slowly spread amongst

whole groups of organisms, including man, we may conclude that such a calamity is apt to lead in turn to serious mutual "misunderstandings," to incompatibilities, and even to deadly antagonisms between normal and abnormal classes or races of men. It will be found that the acromegalic class increasingly embraces a philosophy of life akin to one we have lately heard a good deal of, namely, that of the "superman." These "philosophers" will insist on the superiority of their acromegalic instincts and appetites, despising the mentality of the moderate classes as one needing "vertebration."

I have hinted in Chapter IV. at the danger of a perversion of true thought by bad instincts. Æsop in his fable of the *Wolf and the Lamb*, seems to have clearly realised already that the Philosophy of the in-feeder is different from, and incompatible with, that of the cross-feeder. After all the cross might not be a bad symbol for Biology.

CHAPTER III

THE VALUE OF ABSTEMIOUSNESS

PROFESSOR C. M. CHILD has recently brought out a remarkable volume entitled *Senescence and Rejuvenescence*, which, according to *Nature*, provides "strong biological argument for asceticism."

For fifteen years Professor Child has been making researches upon the age changes of lower animals. His results go to show that fasting and periodic starvation are fairly generally conducive to rejuvenescence. With abundant food, so he tells us, some species may pass through their whole life history in three or four weeks, but when growth is prevented through loss of food, they may continue active and young for at least three years.

Partial starvation inhibits senescence. The starveling is brought back from an advanced age to the beginning of post-embryonic life ; it is almost re-born.

It must at once be said that with the higher forms of animals the possibilities of rejuvenescence are more narrowly limited than with the lower forms, amongst which it is quite a feature. Nevertheless, according to Professor Child, it can be stated that in the organic world generally rejuvenescence is just as fundamental and important a process as senescence. In the Planarian worms which formed the chief subjects of Professor Child's experiments, it was found that the animals reduced in size by starvation resembled the young animals. It is as though these organisms were able to make use of their surplus material by turning it into a new source of energy, thus regaining youth.

Most readers will be familiar with the phenomena of seedless propagation, which method is involved in Professor Child's experiments. It is a form of propagation very common amongst plants, as when we propagate them by "cuttings," or "buds," or "runners," for instance. There is nothing new in the fact that parts of a plant or of a primitive animal are able to reconstitute the whole organism. The novel point is that such "reconstituted" organisms are, according to Professor Child's

tests, "physiologically younger" than those from which they came. "The degree of rejuvenescence," so we learn, "is in general proportionate to the degree of re-organisation in the process of reconstitution of the piece into a whole."

There is good reason to believe, even apart from this evidence, that the virtue of the processes of re-organisation and reconstitution here concerned lies in the fact of a simultaneous reduction of what is best described as a "nutritive overflow." For under what circumstances do such modes of propagation as usual with these Planarians occur in Nature? They occur chiefly among parasites whose existence depends upon over-abundance of nutrition and on sluggishness of life. A fair amount of biological observation goes to show that in nearly all such cases good results ensue from a reduction of conditions favourable to surfeit. A return to moderation, be it voluntary or involuntary, may have the effect, for instance, of bringing back the higher forms of propagation—conjugation or sexual reproduction proper in the place of asexual reproduction. It may have the effect, in other instances, of bringing back the male after many generations of Parthenogenesis. Moderation, in short, is seen to make for virility and health throughout the animal and vegetable kingdoms.

Evidence of similar good effects of abstemiousness in the case of man was produced a few years ago by another investigator, Professor Carlson, also of the Chicago University. He tried on himself the effects of a protracted fast, and felt at the end of it as if he had had a month's vacation in the mountains. The mind was unusually clear, and a greater amount of mental and physical work was accomplished without fatigue. A five day's starvation period increased the vigour of the gastric hunger contraction to that of a young man of twenty to twenty-five (the age of the experimenter being thirty-eight). This increased vigour was retained for at least three weeks after the hunger period. A distinct rejuvenescence was thus observed to result from a fast. Nor were the experiments confined to a single individual or left unconfirmed by ordinary scientific tests.

CHAPTER IV

PARASITISM *v.* SYMBIOSIS

THE conclusion is unavoidable from all the foregoing that Parasitism presents an "immoral" relation, the "bad" and truly "diabolical" feature of which consists precisely in the deadly way in which it antagonises the "moral," or "spiritual" principle of "live and let live." In his little work on *Plant Life*, Professor J. B. Farmer, F.R.S., tells us that some of the non-green plants show "an almost diabolical ingenuity of physiological action, as, for example, when some of the parasites, by emitting an attractive excretion, cause their victims to actually grow towards them."

This being the case, it is all the more curious that Biologists fail to recognise that the principle of Parasitism differs *toto coelo* from that of Symbiosis. Professor Farmer, for instance, although conceding that Symbiosis may be a means whereby different species of plants achieve mutual benefits, economic and otherwise, and hinting even that it may be one of the "secret" methods and processes by which progressive evolution has been brought about, yet provides the following, almost paradoxical, definition of Symbiosis :

There are many other instances of remarkable associations of two or more plants, in which each is in turn more or less *parasitic* on the other or, at the least, lives on the waste products formed as the result of the chemical life processes of its associate. Such an association is often spoken of as symbiosis, but it is evident that the *transition from symbiosis to parasitism* is only a matter of degree. (*Italics mine.*)

This exposition is inadequate and misleading. It is putting the "good" symbiotic on the same level with the "bad" parasitic principle, which is far from satisfactory. Surely if waste products or, for that matter, any surplus products whatever come to be exchanged between "associates," this does not constitute a case of Parasitism, though there be otherwise in Nature a frequent occurrence of the transition from Symbiosis to Parasitism. Such an exchange, however crude at first, forms, on the contrary, the most essential basis of the "good,"

“moral,” reciprocal and healthy life of organisms. Shall we for ever continue to interpret Nature in terms of the chaotic, the diabolical and abnormal rather than in terms of the industrious, moral and normal relations of life? If one organism exploits another without any counter-service, this is Parasitism—the definition is clear and unequivocal. As a result of such exploitation there is ultimately weakness and loss of viability on both sides, and the biological community, too, is a loser thereby. If a relation long held to be parasitical, on closer examination is yet discovered to exhibit an appreciable amount of counter-service and of avail towards life, such relation should *pro tanto*, if not altogether, be considered as symbiotic. The wisest course will be to give a suspect species the benefit of a doubt. Prof. Farmer takes the view that the widespread and important relations between fungi and the roots of flowering plants, for instance, represent a “not very one-sided parasitism.” In my opinion the relation constitutes, on the contrary, a case of Symbiosis, though partially marred by abuse, by the recurrence of depredation. Inasmuch as the relation is thus marred, there is failure of permanence. The same botanist tells us that this association of the root with a fungus is a very intimate one in a large number of instances, and that it occurs in a very great number of plants which would never be suspected of parasitic habits.

Obviously the general character of the plants concerned is too high to warrant a sweeping indictment. The further facts, communicated by the same author, may be said to speak for themselves :

The roots of many of our forest trees produce few or no root-hairs. Instead of this they are closely invested with a hairy coating of fungal hyphæ. Not only do these hyphæ ramify in the soil, but they also enter the root itself. Sometimes, as in the pines, they only pass *between* the cells, and do not enter them, but in other cases, as for example, in orchids generally, they *pierce* the cell walls and enter the living cells. In both of these types of mycorrhiza the fungus is doubtless attracted to the root by substances which have a food value for its hyphæ, just as parasitic fungi are induced to enter the bodies of their victims. But in a mycorrhizal association *the cells of the root control the degree of invasiveness* which the fungus can manifest, and not only so, but they often proceed to actually digest the fungus itself after it has flourished within them, and at their expense for a while. We have here, then, a beautiful example of two-sided parasitism, in which the final balance of profit very clearly lies with the flowering plant. It is practically certain that the fungus obtains

some carbohydrate food, at first at any rate, but in return for this the plant acquires mineral substances in solution, which the fungus absorbs from the soil. A considerable number of flowering plants are unable to thrive unless their roots become infected in this way. (*Italics mine.*)

Evidently we have here a relation of immense mutual advantage, entailing immense benefits also to the biological community at large. The relation involves sacrifices and risks such as the frailty of life everywhere entails. The sacrifices on the part of the fungus do not appear to be excessive, if we consider its low status and the concomitant inability to serve in more perfect ways. Having lost chlorophyll, and, hence, the secret of the essential photosynthetic industry of plants, the fungus has, in its own interest, to be useful as best it may and as its powers allow it to be. The status of the higher plant, fortunately, is in itself a certain guarantee against excessive exploitation of "helpers"—the conspicuous industry and vigour of which (relative to their lowliness) is the best testimonial to the forbearance of their "employers." Obviously the benefits conferred by the relation upon the flowering plant and the world of life generally are very great. The benefits which the fungus receives may be greater than we at present know. The fungus certainly stands in urgent need of Carbohydrates, which an adequate exchange relation with the higher plant can best supply. The fungus pays the price for what it receives. I would here point out that though the "employment" of the fungus be characterised by considerable degrees of compulsoriness, it is a very different thing to be constrained to industry, to mutual aid, and to "fair" service by strenuous and cross-feeding organisms, so modestly and symbiotically disposed as our higher flowering plants, from being forced to yield to totally one-sided "diabolical" exploitation, as, for example, in the case of the crab parasitised by *Sacculina*. In this sense, too, I am willing to believe that service was at first compulsory or obligatory. After all, service is the most beneficial necessity—the sweetest of luxuries. But service is a different matter from slavery, and there is a vast difference in results. The "beautiful example of two-sided parasitism," therefore, on due analysis, emerges as an example of Symbiosis, with mutual service and general avail towards life well accentuated in strong contrast to what results from Parasitism.

So in the case of the leguminous plants, the associated bacillus of which, *when provided by the pea or the clover with carbohydrate food*, is able to

manufacture the essential nitrogenous compounds "necessary for the production of protoplasm by utilising the free nitrogen of the air." (Italics mine.)

Bacillus radicola (says Prof. Farmer), is one of the very few organisms capable of performing the really stupendous task of forcing the very inert element nitrogen into combinations, *provided that it is supplied with the means of obtaining the energy required for the process in the form of appropriate carbohydrate nutrition.* (Italics mine.)

All of which provides an account of genuine work and industry, of mutual effort, mutual stimulation, and mutual elevation of a desirable kind—the very opposite of what is ascribable to Parasitism. Obviously "Capital" and "Labour" have here found a fairly satisfactory *modus vivendi*—having regard moreover to the existing inequalities of status.

We are told that the Leguminosæ have by no means abandoned the absorption of nitrates from the soil. They are far from showing symptoms of degeneration. It even becomes almost unthinkable, according to Prof. Farmer, that degeneration of leaf structure could occur,

inasmuch as the continuous supply of carbohydrates from the green parts is a prime condition of the nitrogen synthesis.

The importance to the organic world of these plants which bring nitrogen into combination (Prof. Farmer continues) in a form that can be utilised by living beings is overwhelming. For apart from some means of maintaining the supplies of nitrogenous food, life itself would ultimately cease to be possible in the world.

The interests of the "associates," as of the world at large, therefore, make it imperative that essential industries shall not be interfered with to any large extent. The industries of the bacillus and of the plant are inter-dependent in the building up from the raw materials of "the stuff from which protoplasm itself can be made." That is to say, that protoplasm itself owes its existence and maintenance to Symbiosis. The object of Parasitism is to obtain supplies of protoplasm by stealth and murder instead of honest toil, and thus it is really countervailing the central industry of life and constituting the opposite pole to Symbiosis.

Again, when Prof. Farmer, speaking of what he conceives to be true Symbiosis, namely, in the case of the lichen, tells us :

The symbiosis only continues to pay as long as the alga is properly exposed to light, and for so long as it is properly supplied with water, together with the small amount of mineral food it requires

(the latter offices being largely discharged by the fungus), this

need by no means to be read as in any way derogatory to the high function of Symbiosis. On the contrary. The writer has merely demonstrated in other words that the requirements of Symbiosis in the vegetable world are: work, photosynthesis, reciprocity and commensurate "cross-feeding." Now Parasitism antagonises every one of these factors. How can it be said to approximate to Symbiosis? Evidently the most essential industry of all, that of photosynthesis, imperatively demands cross-feeding, as a guarantee of continuity. Shall we then be so ill-advised as almost to identify Symbiosis with Parasitism because at the lower rungs of evolution, or in associations comprising the most primitive of organisms—with little development of "character"—the risk is that the delicate requirements of Symbiosis may be occasionally infringed; because abuse of power is a common occurrence, and because transitions from a life of strenuous labour to one of unholy idleness are always possible? Though it be quite true that any infringement of its rules interferes with Symbiosis and makes the association *pro tanto* "unpayable," yet we have seen that permanence of healthy association is in the path of Symbiosis and of Symbiosis alone. There is, of course, more or less "payability" in the different forms of Symbiosis, and the least "payable" forms may be said to approximate the least offensive forms of Parasitism. But, as I have said before, we should not confine our attention to those cases of Symbiosis which hover on the borderland of Parasitism. We should study Symbiosis in its unattached and collective forms in order to obtain a just and comprehensive estimate of its significance, its value and of the way it is sanctioned by Nature. What Prof. Farmer says on another page respecting the immense importance of the elaboration of chlorophyll, that it is "fraught with consequences to the whole organic world compared with which all the other structural products of evolutionary change sink into insignificance and obscurity," applies with equal force to the importance of organic reciprocity and of the necessarily implied cross-feeding.

Work, reciprocity, and cross-feeding, these are the factors constituting "*la vie normale*," notwithstanding all interferences to the contrary. We may glean further confirmation of this truth from the following of Prof. Farmer's statements:

Lichens (he says) are particularly instructive in showing that the form assumed by an organism is in the long run determined by the chemical

reactions [work, domestic and bio-economic] that have gone on and are still going on within it. These reactions are nicely adjusted, and are readily interfered with or encouraged by the conditions under which they take place. The result is perceived in a delicate adjustment of growth whereby the different parts are so correlated to each other [complete domestic and biological reciprocity] that excessive development of one part carries with it its own order of arrest [moderation a condition of reciprocity] whilst deflection of nutrition to or from any part will, of course, correspondingly effect growth in that region [the avoidance of antithetic developments of growth depends upon the earning of such food as is most calculated to maintain the utmost unity in the diversity of parts].

I should say that the instructiveness of the case of the lichen consists in the proof it affords of the truth that only the right kind of work can produce the right kind of reaction, both chemical and biological, and, further, that the right kind of work requires the right or ideal kind of food, namely, such as is non-perverting, having regard to efficiency and permanence of effort and to the delicate requirements of mutual accommodation by the method of reciprocal differentiation.

In telling us of the dreadful ravages of parasites amongst plants, Prof. Farmer points out that we know very little, as yet, about the nature of "constitutional" resistance (to disease or infection), which nescience is not surprising failing the important recognition that health and disease follow in the wake of two antagonistic forces, represented by Symbiosis and Parasitism respectively. Prof. Farmer further says that the environment plays a part in increasing liability to infection, without, however, attempting to specify this part, or to tell us what may be due to "sociological" action and reaction as between organism and the bio-social environment. We are merely told that "presence of nitrogenous manure in excessive quantities" is a "predisposing cause of fungal attack." "It operates in several ways, but often indirectly by causing an undue accumulation of soluble nutritious substances in tissues and cells, the walls of which are imperfectly thickened" (a kind of "osteoporosis," in fact!).

I would, however, point out in this connection that we have here precisely an illustration of the general ill-effects of "in-feeding," with its exaggerated reliance upon organic, and more particularly, nitrogenous material—obtained in the majority of cases by the lazy method of "short cuts," *i.e.*, without due work and exercise and without due biological forbearance, such as are entailed in genuine organic reciprocity. We may conclude that

a method of life which is sociologically inferior, in the end leads to many deleterious reactions, to physiological weakness, to susceptibility and to disease.

It is highly suggestive in this connection that, as Prof. Farmer says, the predisposition to infection in plants is probably connected with a disturbance of the photosynthetic processes, *i.e.*, sociologically speaking, an interference with an essential and widely useful industry, and further, that the "whole matter of immunity is evidently very closely related with nutrition," which again cannot surprise us, as we have now fully seen that a disturbance of nutrition may throw out of gear what is all-important, namely, the highly specialised system of mutual industries upon which is based "organic civilisation."

As Prof. Farmer himself says in the case of flowering parasites, which have lost their chlorophyll: "There is the strongest possible evidence that the change has come about in correlation with the altered conditions of nutrition."

The chief correlation in this connection, in my opinion, is the sociological correlation, which means loss of biological support and of biological sanction. Nor is it that Prof. Farmer is entirely blind to sociological correlations. As a broad-minded observer, he at least calls attention to the existence of sociological sequence on one or two occasions. The tacit implication, however, is that such occasional sociological illuminations are to be regarded as ornamental rather than real—an undue limitation, it seems to me, of the application of Science.

The following passage bears out my remarks, whilst it may be said at the same time to afford an excellent illustration of the strength and persistence among plants of what I have termed the "symbiotic sense":

It is not a little curious that in a large family of plants like the Loranthaceæ, to which both Loranthus and the Mistletoe belong, some species should not have advanced still farther in the parasitic direction. But although nearly all of them draw their water supplies from another plant, they have never taken the final step of absorbing from it the organic food. They have consequently, or perhaps one should say correlatively, retained their leaves, and all the complexity of structure which, as we have seen, the presence of the green leaf entails.

Evidently the retention of some degree of status by a plant is not compatible with large steps in the parasitic direction, with lazy indulgence in food, or with a surrender of the strenuous symbiotic sense which at the same time makes for forbearance

with associated life. More pronouncedly "sociological" still, Prof. Farmer continues thus:

The parasitic habit has appeared independently in a number of other families of flowering plants. In some of them it is characteristic of practically all the members, just as in the Loranthaceæ mentioned above. As a matter of fact, in very many of the larger natural orders or families we also find species which have more or less broken away from the ranks of typical green plants *in connection with their assumption of saprophytic or parasitic habits*. Sometimes we can construct, within the limits of nearly related groups, all the stages, starting from a sort of *dalliance with robbery* which is hardly betrayed by any essential structural change, but culminating in species which, so far as their vegetative structure is concerned, have lost all resemblance to the forms of higher plants. Thus in the alliance or family to which the snapdragon belongs, the familiar little Eye-bright (*Euphrasia*), abundant on grassy downs, the pink Lousewort (*Pedicularis*) of the marshes, and the yellow Cow-wheat (*Melampyrum*) of the woods, all have begun to supplement the *legitimate* stock of food which they manufacture for themselves by stealing from adjacent plants. (*Italics mine.*)

We have seen that the saprophytically inclined fungi amongst plants may yet, by hard physical work, as humble wage-earners (though somewhat precariously) redeem their existence and play a useful part in organic civilisation. Their lowliness of disposition does not, however, entitle them to a high kind of partnership.

What emerges more particularly from considerations such as these is this, that the science of Biology could and should become of immense value as an aid in the conduct of life. It could and should show abundantly, what is of the utmost importance to know, that it is the conscientious organism alone which, strictly pursuing a legitimate pathway of life, and refusing to dally with evil, in the end achieves successful survival.

CHAPTER V

THE LAW OF SYMBIOTIC MODERATION

THE application of the important law of symbiotic moderation is strikingly shown in the phenomena of sexual Symbiosis, as will be seen from a brief consideration of some of the data of Vegetative and Sexual Reproduction, to be gleaned from Prof. J. B. Farmer's *Plant Life*.

Reproduction, in its simplest and most primitive form, according to this Botanist, is one of the most obvious results of growth. "It represents, after a fashion, and in a certain tangible form, the balance of profit over expenditure on the part of the individual, which is applied to the extension of the business of the species or race."

This commendable attempt at an economic interpretation of the reproductive process, is yet, in my opinion, rather incomplete. It does not allow for the difference between a false and a genuine "business," a false or genuine "profit," which difference yet exists and depends upon "sociological" or bio-social factors, analogous to those governing the growth of wealth in human societies.

The nutritional processes (so we are told) which enabled growth to proceed have prepared the way for, and have then given way to, a *new set of chemical processes*, and these result in the cleavage of the mass into smaller parts. (*Italics mine.*)

Here again we have a confirmation of the fact that biochemical processes are anything but primary determinants in organic developments. They are, on the contrary, themselves determined by nutritional processes, which, as we have seen, are in turn regulated by psychical and bio-economic factors, *i.e.*, by the use the organism makes of its powers of autonomy and of industry. With these qualifications, it may be said that nutritional processes, by directing the bio-chemical processes, determine the phenomena of reproduction, simple or complex, as Prof. Farmer insists they do. Simple cell-multiplication, according to Prof. Farmer, is most often determined by "an abundant supply of nutrition."

Multiplicative processes, however, as we are soon reminded, are not identical with those of growth, and, "both in the fungi and in other lowly plants, *nutrition sets other processes in action* which lead to the formation of various sorts of specialised reproductive cells." (Italics mine.)

What emerges is this: great abundance of nutrition sets in action chemical processes favourable to mere multiplication, to mere reproduction rather than higher-production. The production of the "higher" *i.e.*, more specialised, reproductive cells requires a *new kind of* chemical processes. Who or what is it that sets these new chemical processes into action?

Prof. Farmer simply says nutrition. But this reply sets us asking how is it that nutrition, or nutritional chemistry, are able to determine both, mere redundant cell-multiplication, and the almost opposite result of the formation of highly specialised non-redundant reproductive cells? How is it in particular that a strictly limited nutrition seems more apt to conduce to progressive chemical processes with commensurate progressive effects upon reproductive specialisation and evolution generally than almost unlimited nutrition? In order to answer these important questions, we must get behind nutrition as it were, and discover how it becomes capable of influences other than merely sustaining.

Obviously, in the choosing, earning and using of food, the factor of autonomy comes into play. Though this autonomy be incipient on the lowest rungs of evolution, and apt to be at the mercy of many foreign influences, yet it is a quantity by no means to be despised—one indeed of increasing paramountcy with every forward step of evolution. Moreover, the organism as a member of the biological community, is activated also by a kind of corporate autonomy, which is of some considerable significance and must be taken into account. The corporate autonomy represents the greater experience, the maturer wisdom of the race. It is apt to direct choice of food material, and, in general, use of ways and means, towards communal and co-operative purposes—suited as far as possible the wider ends of life. "Private" autonomy, owing to the frailty of life, is often at variance with corporate autonomy, opposing and frustrating its ends. Harmony between the two autonomies produces the best results in evolution, such results expressing themselves in gains of individuality, in gains of chemical powers and of status. Given such harmony, food and

nutrition may be said to play the rôle of servants rather than of masters. Indulgence is avoided, and choice and use of food are so regulated as to serve the highest ends of the community *pari passu* with those of individuality rather than those of the opposite purpose, of mere sense gratification with unrestrained multiplication. Such is the way in which genuine "profits" are arrived at in evolution. The way involves the roots of honour. Disharmony of autonomies, on the other hand, leads, by way of a loss of sense of proportion, to more or less "extreme determination" of the organism by the environment. Food and nutrition become, as it were, the masters, at the expense of autonomy and of progressive evolution. Notwithstanding superabundance of nutrition, there is no genuine profit. There is, on the contrary, a loss. Everywhere we get a contrasting evolutionary result in accordance as to whether nutrition is the servant or the master of the organism. It may be said, therefore, that the adage "*noblesse oblige*" is as old as the hills. "Private" autonomy has had to submit to limitations, to the superior demands of communal autonomy from the first, and this in view of the interdependence of life, and inasmuch as a gain of individuality could only have been accomplished with the aid and sanction of others—of biological helpers, as instanced by the phenomena of Symbiosis. We have seen that the system of natural ethics as entailed by Symbiosis is all-important to life. We are warranted, therefore, in interpreting the almost universal need of restraint of feeding, characteristic of the reproductive period of higher organisms, as typifying the law of "symbiotic moderation."

Such, then, is the secret of the mysterious protean power of nutrition—a power varying in evolutionary effects with autonomy, with conscience, with honour, with duty. More often than not, the important "geistige Band" (spiritual nexus), as Goethe would have termed the relation of individual to communal autonomy, is overlooked, with the result that the true and complete significance of nutrition is lost sight of. Specialists abhor inter-connections, and the specialists of inter-connection itself are few and timid. To put the case of nutrition differently, we may say that if the "business" of a species is at all needed in the organic world, there have to be furnished adequate supplies of food energy from the common fund of life, both for maintenance and for reproduction. A species may be considered

as a branch of the tree of life, the branch receiving its main directions of growth from the tree, which in the first place furnishes pabulum and restraints adequate to the widest contingencies of life—the autonomy of the branch being subordinate to that of the tree. The well-being of the tree depends in turn upon the work of its branches ; tree and branches mutually determine each other. That individuality looms behind the processes of Nutrition and Reproduction, is adumbrated by Prof. Farmer, when he says, for instance, that :

In the evolution of the more complex plants, the cells—the primitive individuals—become organised into a higher individuality, or when he shows that the nucleus, the true determinator of hereditary qualities and of the chemical changes proceeding within the protoplasm, is the seat of individuality.

To make individuality the starting point of our investigations, is undoubtedly the best method of obtaining light on the otherwise mysterious ways of nutrition. Such method enables us to transcend the narrow confines of physical, chemical and physiological divisions and leads to a comprehensive view of the matter without injustice to any one associated factor. It throws light on the great significance of food habits for instance. It enables us better to realise how it is that different food habits must eventually entail different lines of evolution.

Prof. Farmer recognises that there is a great change of point of view if instead of thinking of the multiplication of cells as reproduction in the abstract (irrespective of individuality), we think of the unit organism (the individual) undergoing transformation. The latter point of view he would apply more specially to the higher, *i.e.*, more complex forms of Reproduction, *e.g.*, when new colonies of cells, and not new cells merely, are started ; that is to say, when individuality and the necessarily implied autonomy come more pronouncedly into purview.

Coming to sexual reproduction proper, we learn that it occurs in almost all the divisions of the animal and vegetable kingdoms, although it has not as yet been detected in some of the lower groups. These consist either of organisms of extreme simplicity, or of those in which we have grounds for believing that sexuality has been lost, probably in connection with special conditions of nutrition. In some of the higher plants the sexual function has degenerated, though we cannot clearly trace the loss to any definite cause.

Bio-economically speaking, the loss referred to in this passage is one that has to do, I believe, with bad methods of food-getting,

rendering the "business" and "profits" of the species illegitimate, and virtually constituting a divorce from biological Symbiosis, with the result of a distortion of domestic and sexual Symbiosis. It is clear that a considerable degree of co-ordination, of co-operation, of dutiful and complete performance of function, is required from every part of a complex organisation in order that it may duly procreate the polity as a whole—a process which probably, as Darwin suggested, and recent research seems to some extent to confirm, involves a complicated method of Pangenesis, together with other complicated processes entailed in fertilisation. Sexual reproduction, in other words, in order to be successful, requires the co-operation of all the conditions favourable to a high degree of reciprocity, such as effort and adequate moderation and restraint—in fact the identical conditions which we have found to be indispensable to successful biological Symbiosis. The "reduction" processes characteristic of fertilisation may be viewed as purporting in part the return to conditions of simplicity and of moderation in the very constitution of the organism; and fertilisation itself may be regarded as in part a process of rejuvenation by means of a riddance of superfluous material—superfluous "profits." The organism is passed through the unicellular stage so as to be equipped (so that the race may be restarted) with all, but with no more than what is strictly necessary, for perfect socio-physiological function. Where surfeit, *i.e.*, over-feeding, occurs, fertilisation is altogether impeded. A fast is often the equivalent of fertilisation in restoring rejuvenescence to the species. Evidence of this effect may be abundantly culled from Prof. Farmer's pages, who also notes in this connection the antithesis on which I have insisted between individuality and redundancy, as when he says that

The sexual act itself stands in strong antithesis to vegetative propagation, for it does not directly involve an increase, but a reduction in the number of cells. Two cells which we may call the *gametes*, are concerned in the process, and they invariably coalesce to form one—the *zygote*.

The uniting cells, I would add, stand in a relation of reciprocal differentiation to one another, that is in a symbiotic relation—a truth which needs emphasising over and over again. The behaviour of the uniting cells warrants the inference that they conform to the rules of Symbiosis. On any other explanation their behaviour is quite unintelligible and mysterious, as the

following passage abundantly confirms. Thus in the case of *Chlamydomonas media*, we are told :

It is possible to maintain the plant, apparently for an indefinite period, in a state of vegetatively active growth. On the other hand, it may with almost equal certainty be compelled to enter on the sexually reproductive phase of its life. A sudden starvation, *if previously well nourished*, and so long as the organisms are exposed to light, will at once bring about the change that leads to the formation of gametes. But we may at once confess that *we do not as yet understand how these conditions work in producing the observed effects. Nor are we able to form a clear idea as to why the addition of nutritive salts to the water in which the chlamydomonas is living suffices at once to arrest sexual development, and to switch the life processes back on to the vegetative course ; so much so, indeed, that even gametes can develop independently, and in a vegetative manner, i.e., without any sexual union.* But the effects of sudden starvation on previously well-nourished organisms are well known to conduce [as long since laid down by Herbert Spencer] to the development of sexual reproductive organs. In a chlamydomonas, the organism and the sexual cell are practically identical, and it is in the highest degree suggestive to find that what stimulates the production of sexual organs in a complex and highly differentiated plant, will also cause the undifferentiated primitive one also to enter on a sexual condition or phase. Moreover, the converse is also true, though it is often less easily demonstrated. For a reversal of the conditions that led to the development of the sexual state will arrest it, and cause not only lowly, but many of the higher plants to resume their vegetative growth. Some of the malformations often seen in flowering plants, as the consequence of injudicious manuring, represent the results of the antagonism between the sexual and vegetative functions. (*Italics mine.*)

And what is it that these typical phenomena are so highly suggestive of? It is this: that the requirements of interdependence are such as to impose upon organisms the necessity of strict limitation of sense gratification—contrary to the current idea that all appetites are equally normal and equally sanctioned in Nature. The proviso, “if previously well nourished,” signifies that at one time there was an impending overflow of nutrition, due to indulgence. With a return to a tolerable physiological rectitude of life—to symbiotic moderation—the sense of proportion reasserts itself, and the organism, duly receiving again support and sanction, progresses along the path of increased individuality and increased biological specialisation. The return of sex proper, with its normal proportions of numbers, coincides in every case with the return of the species from a career of non-symbiotic indulgence to one of symbiotic rectitude. A plant injudiciously manured, is a plant injudiciously fed, and, hence, interfered with in its general integrity, with the result of pathological

development such as malformation or monstrosity. I would recall the famous experiments of Maupas with a common infusorian (*Leucophrys patula*), showing that with plant food (cross-feeding) the rate of asexual reproduction is much less than with animal food (in-feeding), reproduction tending towards conjugation—the higher mode—rather than towards fission—the lower mode. In the same way, Yung, who fed tadpoles alternatively on beef, fish and frog's flesh (note the gradual intensification of the in-feeding), obtained the following results as regards the ratio of male and female: first brood percentage of females, 54-78; second brood, 61-81; third, 56-92. (The tadpole in the normal state is a cross-feeder; but such considerations are usually entirely disregarded.)

As soon as we recognise that normal life is characterised by symbiotic proportions, the mystery of not a few experimental results is easily solved. Invariably it will be found that the lower forms of propagation are associated with lower forms of Symbiosis, and that the respective inferior bio-social methods of life lead to various incompatibilities, as between the contrasting interests of the lower and the higher orders of life. The antagonism between the reproductive and vegetative functions is *au fond* the antagonism between progressive and reactionary bio-social tendencies within the great world society formed by plants and animals on our globe. The "sociological" interpretation of nature is thus congruous with common sense, with observed facts, and congruous also with our best knowledge.

CHAPTER VI

THE BIO-ECONOMICS OF INTERNAL SECRETIONS

THE subject of internal secretions is coming into great prominence in Physiology. Mr. P. G. Stiles tells us in the *Scientific American*, Supplement, No. 2,169, that it will doubtless occupy a larger and larger place in future expositions of Physiology. This is what we are told by way of introduction to the subject :

One need not be a profound student of science to appreciate that the co-ordination of activities is a most striking fact of animal life. What happens in one place is adapted to what is occurring at another. It may fairly be claimed that each part acts more distinctly for the good of the whole than for its own advantage. Clearly, this could not be the case if there were not some mode of transmitting influences from organ to organ. When one considers the possible means of such transmission, the nervous system is at once suggested. This wonderful structure is so fashioned that, conceivably, any part of the body may definitely affect any other. It is in this respect like a telephone exchange which affords to each subscriber the opportunity to communicate with any other. The nervous system has long been looked upon as the essential instrument of co-ordination. A second possibility has lately become unexpectedly prominent. It is the transmission of chemically active products through the medium of the circulation. Such products of the tissues are usually called internal secretions. A compound added to the blood by one organ, will, within a minute, be quite uniformly diffused over the whole body. There is no way to limit its distribution and bring it all to bear upon a restricted portion of the system. In this respect the interchange of influences by means of internal secretions lacks the refinement and precision which characterise the nervous correlation. We have to do with a set of drugs which, like those administered by the physician, must be offered to all the tissues—to those which seem indifferent as well as to those which are evidently responsive.

It is clear that Mr. Stiles visualises the internal or "physiological" economy of the animal as constituting essentially a case of Symbiosis. There is—at least in normal days, we may assume,—a pronounced systematic reciprocity between the parts. If it can be said that "each part acts more distinctly for the good of the whole than for its own advantage," then we have here, not a mysterious altruism, but a symbiotic subordination of minor autonomies to superior autonomy. The

greater good of the community takes precedence. The principle involved implies that no part or organism can afford to be riotously indulgent in any of their ways, lest this lead to serious clashes in the shape of antagonism, warfare, infection and disease. The significance of internal secretions, therefore, cannot be even half understood by exclusive reference to mechanical transmission of chemically active products. It is the partnership and "duty" aspect of the matter which is of paramount importance.

We have to do with substances secreted by one organ which can influence others at a distance: chemically and without intervention of the nervous system. This, according to the orthodox Physiologist, is remarkable, for he has hitherto looked upon the nervous system as enjoying the monopoly in co-ordination, seeing that it physically attaches organ to organ. In the absence of such attachment, the Physiologist finds co-ordination difficult to understand. Yet with the now disclosed fact of marvellous "stimulation at a distance," "physical attachment" must retreat into the background and make room for co-operation—evolved and irrespective of attachment. The term "internal secretions" is to some extent a misnomer, inasmuch as it is apt to cause it to be overlooked that the vital potencies of these body-fluids are in reality derived from the plant, which alone possesses the necessary synthetic powers of manufacture. Mr. Stiles probably takes it for granted that the ingredients of the glands must first be in the blood, and, again, that in order to be there, they must first be in the food. But he does not tackle the subject of origins in this connection, and, in my opinion, rather detracts from the importance of glandular secretions by identifying them with drugs. This identification he tries to justify by saying that in either case the stimulation is offered *in toto*, *i.e.*, diffused by the blood over the whole body. But there is a vast difference in the respective applications. The drugs of the physician are something artificial and may or may not reach the part they are intended for. They may or they may not effect the desired changes. Though they reach the affected parts, they may do such damage to others as to render more difficult than ever the restoration of the natural balance of secretions on which health depends. The internal secretions, on the other hand, have behind them, as the norm of life, the sanction of symbiotic evolution and are, therefore, ideally adapted as natural media of harmonious

stimulation. If, as Mr. Stiles says, there is no way of limiting their distribution and bringing them to bear upon a restricted portion of the system, as might be conceivably of some benefit in the application of drugs, such limitation of the operation of internal secretions may not be in the least desirable or beneficial to the organism. I should say that health and growth depend precisely upon a uniform diffusion of these special products of the joint evolution of plant and animal, the effect of which is to stimulate all parts harmoniously to co-operative and widely useful work. Mr. Stiles concedes that the body needs a "slow and uniform delivery" of internal secretions, as though having regard to the requirements of symbiotic moderation. It is not enough, however, to say that the glands, as the suppliers of indispensable normal stimulations, work according to "duty," and to leave it there. We must recognise that they require in turn to be treated according to "duty." For instance, they require to be supplied by the organism with raw material that avails to life in the fullest sense of the word. This necessitates an adequate supply of special, matured food—food, instinct with influences congenial to a permanent and harmonious co-operation of the parts. And such "tutored" food, increasing in adequacy with every higher degree of Symbiosis, and ideally equipped with potencies diffusable with great benefit and without injury over the co-evolved animal body, can only be obtained with the help of symbiotic vegetable partners.

We are told :

At the back of the abdominal cavity, above the kidneys, are the paired structures known as the adrenal bodies. Insignificant as they appear, they are vital organs, the removal of which is followed swiftly by prostration and death. Something must go out from them which gives tone and efficiency to more than one system. When the adrenals are gradually wasted by disease, the failure of strength corresponds with the degree of their destruction. Their extracts do not successfully compensate for the lack of living cells ; the body seems to need a slow, uniform delivery of this internal secretion, and periodic dosing does not prove equivalent to the natural condition.

And what, again, is the "natural condition" in which all the parts may be slowly and uniformly, *i.e.*, moderately and harmoniously supplied—in a manner not to be equalled by artificial means? It is the condition provided by a symbiotic relation with the implied reliability of support and the

implied constancy and regularity of exercise of the parts. There are also internal secretions at particular times, and Mr. Stiles tells us that

we have the best of evidence that the adrenals can thus be thrown into a temporary activity far beyond their ordinary performance. The particular occasion for this is one of stress and excitement. It has been clearly proved that at such times the chief product of the adrenal cells (adrenin) is increased in the blood. It has also been proved that this internal secretion confers upon an individual the utmost command of his physical resources.

We may take it that great irregularity of glandular action, commensurate with the irregularity of ill-gotten supplies, is the norm amongst predaceous species, which, as the result, if they have more excitement of life, are yet in the end left with diminished strength and endurance, and with uncouth, ill-shapen bodies. As regards the origin of Adrenaline, according to Prof. Gowland Hopkins (see his Presidential Address to Section I., Brit. Assoc., 1913), it is derived from one of the "aromatic" amino-acids, *i.e.*, in my view, from one of the "building stones" specially hall-marked as of vegetable extraction. Prof. Hopkins remarks in this connection: "Facts of this kind will form a special chapter of bio-chemistry in the future."

In the same address it is pointed out that in connection with certain important proteid reactions, the carnivore behaves differently to the herbivore,* the latter showing greater powers of synthesis and of defence, which seems further to corroborate my view that growth and evolution are determined according to the varying degrees of Symbiosis existing between animal and plant.

* One of my French zoological critics (*Année Biologique*, Vol. xxi.), evidently a believer in "*de gustibus non est disputandum*," finds fault with me for asserting that it makes a difference in evolution whether a species habitually ingests animal or plant protein, and he thinks it doubtful that my theory will cause "*la biologie positive*" to take a forward step. One must not, however, abandon all hope.

CHAPTER VII

THE LAW OF THE MEMBERS

ANOTHER Biologist, Prof. E. W. MacBride, speaking of internal secretions (*Presidential Address, Sect. D., Brit. Association, 1916*) shows himself to be fascinated by the Pauline idea that "if one member suffers, all the rest of the members suffer with it." Yet the full biological implication of this observation is little realised, as little indeed as is the fact of the existence of a genuine biological community, held together by work and partnership, the legitimacy of the ensuing capital depending upon bio-moral factors, *i.e.*, upon the serviceability of organic wealth to fellow-organisms ("members" in the biological sense).

The neglect of the "Sociology" of inter-relations is all the more astonishing as evidently Biologists could not help noticing that often the relations between organs ("semi-independent organisms"!) partake of the sociological order. One reason for this neglect is that sociological and economic study is not particularly congenial to Biologists; another that the prevailing fashion in biology favours purely mechanical interpretations.

Prof. MacBride's way of treating the "law of members" is a case in point. Instead of examining the application of this law in connection with the correlated activity of the glands, he shelves the whole matter, getting rid of the difficulty by invoking one of the most abused of biological catchwords, namely, the "environment"—a veritable *deus ex machinâ* of Biology. This term, if it is not to be entirely discarded, should, in my opinion, at least be clearly defined, so as to be used with the least possible indeterminateness. Not enough, however, with an undefined entity of "environment," Prof. MacBride conceives of the organism as possessed of a kind of internalised entity in the shape of an "inner environment" (an inner "outer") which he employs, *inter alia* to supplant a rival entity, namely, the Aristotelian "entelechy" revived by Driesch. Instead of admitting that organisms capitalise the results of joint work in the shape of

capacities and of valuable substances, in accordance with bio-social rules, Prof. MacBride posits an "internal environment," capable, in his opinion, of emitting "organ forming stimuli," with the help of "specific organ forming substances," the discovery of which substances he hails as the great epoch-making event in experimental embryology.

Such invocation and inversion of "environment" is an alternative, but, in my opinion, an inadequate, way of stating the case of the inter-connections of "semi-independent organisms" (organs)—connections closely associated in turn with those between independent creatures, *i.e.*, between organism and organism in the bio-social and bio-economic sphere. The fact of the appearance of "substances," however, coupled with the fallacy that "environment" is a chiefly physical agency, helps to weigh the scales against a due sociological view, and provides justification in the eyes of our Biologists for emphasising physical at the expense of sociological factors.

So long as there are catchwords, and so long as there is "substance," so it seems, the Cult of Physical Science is assured, and, though there may be an occasional flirtation with Pauline views, what one might describe as "spiritual law in the natural world" is ordered out of court.

As regards the suggestion of the "environment" (mainly animate) entering the organism, we have seen that, in virtue of due reciprocity, in some cases of attached Symbiosis a kind of "garden" (in the shape of strenuous green cells) may indeed be said to have entered the organism. We found that permanence and success of organisms thus compounded depend entirely upon the degree of biological righteousness inherent in the association. Parasitism we found to represent the perversion of the fundamental and righteous principle of organic association. We inferred that on no account can the relation between organism and "environment" be regarded as a purely physical matter. We may say, therefore, that "internal environment" at most can only mean that the organism, as a result of its transactions with others, has duly capitalised its experiences, its wealth of relations, and has learnt to use its stored capital as though to some extent independent of immediate external supplies. If the "internal environment" is not to be another "entelechy," it can only mean an acquisition on the part of the organism, purchased by its "labours"—not anything separate in accordance with the

usual connotation of the term "environment," but something inseparably built into the organism's flesh and blood. If the organism has by due labour and due exchanges woven biological raw material into its own inner fabric, it seems more justifiable to speak of capitalisation than of "inner environment." I would ask the reader to consider which view is the more judicious and also the less equivocal, that which posits an "internal environment" irrespective of any but physical laws, or that which emphasises the acquisition of capital by adequate efforts under adequate duties and responsibilities—all transformation being the result of work and of exchange of surplus products.

To quote Prof. MacBride in extenso :

We have been gradually led to view the nucleus as a storehouse of all the characters of the species and to look for the cause of the first differentiation seen in development in the modification of the cytoplasm through the emission of substances from the nucleus; but to attribute much of the later development to the modification of one organ through the influence of materials emitted into the body-fluid by another organ, so that we may compare the organs of the growing body to an assemblage [partnership !] of *semi-independent organisms* which constitute an environment for one another [another way of saying that it is the symbiotic relation which constitutes the essence of an "environment."] We all know from medical evidence that there exist certain organs of the body—the so-called ductless glands or *Endocrine* organs—whose secretions have enormous influence both on the growth and the function of all the other organs of the body. The question then inevitably occurs to our minds whether all the organs of the body may not exercise the same kind of influence on each other to a lesser degree. (*Italics mine.*)

Reasoning further from considerations such as these as to the probability of the inheritance of acquired characters and as to the plausibility, in a somewhat modified form, of Darwin's hypothesis of Pangenesis, Prof. MacBride concludes that many features of the adult are due to the interaction of, and the modifications induced *in, one another* by the growing organs of the individual. He argues further that

these modifications *are similar in nature to those produced by the external environment* (animate rather than physical, I should add) and, like the results of external influences, tend in time to become ingrained in the constitution of the organs on which they act. (*Italics mine.*)

All of which may be simplified by saying that evolution is due to a double, *i.e.*, an internal and external form of Symbiosis with the implied work, the capitalisation of the results and the momenta inherent in the respective bio-social processes.

CHAPTER VIII

“PATHOLOGIA PHYSIOLOGIAM ILLUSTRAT”

IN a very interesting article on *The Natural History of Tumours*, in *Science Progress*, April, 1916, Dr. C. Mansell Moullin, M.A., places before us the following considerations :

Division of labour means that every part of the body *has to undertake a particular kind of work ; particular work entails a particular chemical reaction. The more thoroughly the work is done* the more completely does this special reaction predominate over all the others at that particular spot. This, continued in the same group of cells for generation after generation, of necessity involves progressive modification of chemical constitution and of structure or in other words development. (*Italics mine.*)

This socio-chemical account of development is to help us to understand how, through some chemical disturbance in the system, a tumour may be formed. In my opinion, however, chief stress needs to be laid upon the dependence of the chemical factor upon “work,” which is of much greater significance than this otherwise suggestive passage would lead many to suppose. Equal stress must be laid upon the concomitant factor of “division of labour.” Neither factor can be casually treated or dissociated from its wider economic and sociological implications. Chemical force, I insist, is engendered in the body by the mutual work of the parts, and this, and chemical evolution generally, depends mainly upon the “alchemy” of Symbiosis, a beautiful illustration of which we saw in the case of the lichen. We emphasised there, what is again becoming apparent here, that without the right kind of Bio-chemistry no lasting “partnership” is possible, and that this requires above all the right kind of “work” on the part of the organism. We found that Symbiosis represented a veritable “Madonna delle Salute,” and we must recognise it also as the presiding principle of bio-chemistry, if we wish to get at the foundation of the organism’s viability and resistance to disease. Although in Dr. Mansell Moullin’s outline of progressive modification of chemical constitution we get references to “a particular kind of work,” to “thoroughness of work,” to “permanence of work,” yet the connotation of

"work" is not sufficiently sociological, and he evidently lacks a persistent principle regulating the work and the divisions of labour and directing them into their right channels.

Dr. Mansell Moullin invokes the authority of the late Prof. Ehrlich to the effect that "the process of chemical evolution is still going on." This fact to me scarcely seems to need proof. Such evolution is still proceeding inasmuch as interaction and work are still proceeding.

In a dissertation upon tumour-formation, with its excessive proliferation of cells, the question inevitably arises what is it that, in normal days, keeps the cells, generation after generation of them, to their true work? Is it from sheer inclination or from compulsion that they keep to the path of integrity? And what is the nature of either or of both? Some no doubt would clinch the matter and shelve difficulties by answering "natural compulsion." I contend that the most rational explanation, which accounts for the specialisation of work and its biological connections and for what "good will" and "compulsion" there exist, is one which considers the normal physiological and biological relation of units to be one of Symbiosis.

Obedience to the law of Symbiosis, compelled by bio-economic and bio-social necessity, that is the compulsion and also the good will in the matter of integrity of the cells. To transfer instead compulsion and good will to the stars and nebulae is a mere Naturalist's artifice, which should no longer be countenanced in Biology, nor in modern thought.

We are further told :

The development of the individual is in part the product of the chemical reactions that have taken place in its ancestors from time immemorial, handed down by inheritance from generation to generation, in part the result of the chemical changes that are taking place in its own tissues at the present time.

This is a mere "historical" instead of a qualitative, account. There is no allusion to the fact that we may have in the organism before us a "*damnosa hereditas*." Yet this should be fully noted ; and nowhere more than in a dissertation upon pathological growth. A race or a species may have behaved badly, *i.e.*, anti-biotically for more than one generation, and its physiology and bio-chemistry must consequently be abnormal in commensurate degrees. Dr. Mansell Moullin states further :

The essential point is that all development, like growth, is ultimately the outcome of chemical changes in the tissues and that everything that

interferes either with the inheritance of the products of past chemical changes or with the effects of present ones, interferes with the development of those tissues, so that they remain on the same plane as their racial ancestors, and enjoy the same powers of reproduction.

This, however, is still far too physical an account of the arrest of development such as usually leads up to the incidence of tumours. We are merely enabled to see that there must have been some chemical disturbance, some interference with the "normal" bio-chemistry sometime and somewhere. Evidently there was at one time an orderly chemical evolution, whatever it was that constituted the "order."

The effect of the mysterious disturbance evidently is to abrogate a previous wholesome restraint of cell-reproduction and to restore to the incriminated tissue a liberty, or rather licence, of reproduction comparable to that it once "enjoyed" in primordial times, long before it had formed intricate "partnerships" with other cells or tissues. According to the *tout-ensemble* view, a reduction has taken place in the range of that widely useful co-operation upon which the complete realisation of development primarily depends. This allows only of stunted, aborted and ill-directed development. The later and higher phases of evolution consequently tend to be obliterated, and, in, proportion as the special forces, momenta and substances which formerly, as a result of high co-operation, maintained and directed these phases, are in course of dissipation, some more primitive phases of life are prone to re-assert their dominance. The higher control has gone with the higher integrity. There is a contraction in the life of the respective tissue commensurate with the contraction in its socio-physiological usefulness. The cells comprising it are "reverting," *i.e.*, preferring "private" to "corporate" autonomy and spurning, as anarchists, the superior laws of the polity to which they yet belong. The result is friction and disease.

Dr. Mansell Moullin continues thus :

So little is known of the intimate nature of the chemical changes that take place in the tissues that it is not easy to cite instances in which the failure of any particular reaction has led directly to the cessation of development and the birth of a tumour.

This recalls the story of the purloined letter for which the detectives groped in every corner of the room while all the time it lay openly on the table. In my opinion the direful effects of non-symbiotic feeding fully account for the failure of normal chemical

reactions in the tissues. Very special injurious stimulations, of course, occasionally supervene and produce special accelerating pathological effects. In the majority of cases, however, we may take it that a distinct diathesis, due to pronounced metabolic deterioration, obtains and is a fundamental cause of serious failures of development. In my view, the exuberance of tumour tissues and the concomitant cessation of vital development in other directions is on a par with the well-known redundancy and its direful degenerative concomitants so characteristic of Parasitism. In either case, I believe, we have a diathesis primarily caused by faulty food stimulation. I would indeed comprise the "*misère physiologique*" in both cases under the general category of "parasitic diathesis."

Dr. Mansell Moullin thinks that there are many isolated facts suggesting that failure of a particular bio-chemical reaction is the direct cause of the cessation of development and the formation of tumours. One of these facts, he believes, relates to the occasional disappearance of tumours.

It is well known (he says), that tumours, especially those of the embryonic type sometimes stop growing, diminish in size and even disappear under the influence of remedies which can only act through the medium of the *general nutrition*. (Italics mine.)

We are thus getting well on the trail of the "purloined letter." The next step would be to scrutinise the adequacy of the general nutrition—an investigation to a certain extent "taboo" with the powers that be in medicine.

We are also told that the tumours that so often follow the continued application to the skin of soot, tar, paraffin, and the like, arise in a similar manner. Some substances were absorbed which, in course of time, affect the nutrition and functional activity of the skin, so that it becomes harsh and dry to the touch. This, then, is further confirmation of the fact that food is seriously implicated, and the observation is well worth pondering for another reason: it is important from a diagnostic point of view. The "ash" and dry appearance of the skin, in my opinion, is a tell-tale symptom revealing an advanced "parasitic diathesis." The skin is an important organ of elimination, which suffers in efficiency of function and likewise in appearance from the cumulative effects of mal-nutrition. Its morbidly pale appearance in cancer and also in the case of many parasites indicates that there is an encumbrance out of all proportion to the powers

of elimination. The normal ratio of ingestion and elimination is inverted, precisely as though it were a case of too much "take" and too little "give" on the part of the offending species. And the respective disproportion, the respective diathesis, and the respective "social" disposition are hereditary—such is the reverse or pathological side of the "hereditary principle" in Nature.

Dr. Moullin's distinctive explanation is as follows :

The cells that compose it (the skin) *cannot carry on their work as they should*. Their development, which depends upon the chemical changes that take place in them during their work, remains imperfect. It comes to an end *before it should*, while the cells are still in a stage that was perfect for their remote ancestors, but *should only have been* a transition stage for them, and, as a consequence, at a time when they are still capable of exercising the powers those ancestors possessed. The result is the formation of a bud, like the buds that were thrown off from time to time by their ancestors, capable of independent growth and composed of cells, the rate of whose growth and multiplication depends upon the maturity of the parental stock at the moment. If the affected cells have all but reached adult age before the interference is felt, the buds that grow from them are all but adult too. The tumour is composed of tissues that resemble those of the normal skin. But if, owing to irritation, whether it is mechanical or chemical or due to the reaction of living organisms, there is a great increase in the proportion of young rapidly growing cells, and if the development of these is checked in their youth, the buds that spring from them resemble them, and then the tumour increases rapidly and spreads wherever it can. (*Italics mine.*)

This is an interesting chemico-embryological view of the dissolution of one-time wholesome relations of cells leading up to the anarchy that allows of tumours and cancers. It contains, however, I contend, far too casual a reference to the attendant chemico-economic factors, which are more fundamental, I believe, than the chemico-embryological. Evidently there is a great deal of incompleteness and of curtailment of development—as the result of what? As the result of incomplete "work" on the part of the individuals or species. We have seen that only essential, *i.e.*, symbiotic work conduces to a wholesome exercise of all the parts, failing which there is glandular anarchy. It is not difficult for a Biologist to read between the lines of the above passage that there obtains a distinct diathesis determining the formation of buds, due to a fairly general impediment of function and a loss of integrity. On the "sociological" side we see a reversion as

from a highly civilised to a primordial savage state, from the mutuality and security of a "city," to the loose and insecure life of cannibal society.

I would again emphasise the close analogy with Degeneration in Nature. The possibilities of degenerative reversions and abortions are the greater, the lower we descend in the evolutionary scale. A fully extended reversion is not compatible with the status of a higher organism, which yet, if parasitic or predaceous in habit, cannot escape drastic penalties in the shape of suffering and disease. Dr. Moullin tells us that there is a tendency of the same kind of tumour to occur in members of the same family at about the same time of life, which again emphasises the biological analogy of Degeneration. For, as Darwin already insisted, it is a general and important rule in Biology that "at whatever period of life a peculiarity first appears, it tends to reappear in the offspring at a corresponding age, *though sometimes earlier.*"

I have italicised the last three words from Darwin, because they seem to point to a diathesis—a gradual undoing or dissolution of the particular species or family. These "peculiarities," in my opinion, for the most part appertain to the non-symbiotic and pathological order. This being so, we have to see in the ever earlier incidence of "peculiarities," and of other more obvious symptoms of disease in every new generation, an indication of the progressive impoverishment of the protoplasm, tantamount to a curtailment of adult existence. Speaking "sociologically," we may say that there is an increasing veto against the species, a diminishing sanction of its existence. The "wages" of a prolonged transgression against the law of Symbiosis is thus indeed death—in the shape of diathesis, dissolution, and of a kind of Paedogenesis—precocious sexuality—very ghastly forms of which are to be found amongst rank parasites.

Dr. Moullin concludes—again I would say rather "historically"—that tumours are the products of the innate power of asexual reproduction present in some degree in all tissues, except perhaps the most specialised of all. The question therefore arises what is it that determines the way in which the innate powers of Reproduction are turned to account, good or bad? And the answer, as I believe I have shown, lies in the application of the "sociological" factor to evolution. I have also insisted, in this and in former volumes, that the asexual is an inferior method of

reproduction, and that a reversion to it from an erstwhile sexual form of reproduction, means a loss of status, closely associated with a loss of symbiotic potential. Nature, however, can ill afford a serious loss of symbiotic potential, which would entail a serious loss of indispensable "high-class labour." Nature, therefore, abhors perpetual "asexualisation," as she also abhors perpetual in-breeding, and perpetual in-feeding, and above all Parasitism. Though her retributive processes may frequently be veiled from our vision, yet it can be stated pretty generally that in one way or another the transgressors against her "socio logical" laws are ultimately brought to book.

Though He stands and waits in patience
With exactness grinds he all.

And that all this is true is the most important lesson to be learnt from the Bio-chemistry of tumours, the most valuable *morale* to be gleaned from the study of pathology.

Dr. John Beard, who has long defended the view that one form of cancer is due to an "irresponsible" asexual generation or growth occurring during the sexual generation period of the life cycle, has shown that the asexual generations of many animals are rapidly killed and digested by pancreatic ferments (Trypsin and Amylopsin), whereas frequently, on the other hand, the sexual generations are not in the least affected by these enzymes. This points to a biological antagonism between sexual and asexual modes of reproduction, or at any rate it shows the inferiority of the latter because of its frequent more or less pathogenetic, or "sociologically" inferior, origin, which easily renders it a source of danger to biological progress and calls for repressive measures in the protective adaptation of the progressive types. Dr. Beard suggests indeed, that the difference of composition has to do with this biological ("sociological") antagonism between strenuous and pathogenic organisms, and he tells us that asexual forms are built up of dextro-proteins, whilst the sexual are built up of laevo-albumins. He contends that the "micro-organisms, bacilli, etc., of disease are of necessity composed of compounds which are, stereo-chemically, antitheses of those making up the normal human body—and that when they are compared with the pancreatic ferments, the like is true of the ferments by means of which they effect their ends. Only by means of such antithetic or opposite characters of compounds and of ferments produced

by them could such disease-inducing organisms bring about their ravages.

Here again, then, we have an illustration of the everlasting difference between right and wrong in Nature, and here again we can make profitable application of the maxim that *Pathologia Physiologiam illustrat*.

CHAPTER IX

FOR "PROFESSIONAL" SERVICES RENDERED

FROM the late Dr. Alfred Russel Wallace's *Darwinism* we cull the following interesting data :

It is, however, when we come to true fruits (in a popular sense) that we find varied colours evidently intended to attract animals, in order that the fruits may be eaten, while the seeds pass through the body undigested and are then in the fittest state for germination. This end has been gained in a great variety of ways, and with so many corresponding adaptations as to leave no doubt as to the value of the result. Fruits are pulpy or juicy, and usually sweet, and form the favourite food of innumerable birds and some mammals.

I should say that we have here evidence of biologically "good" attractions, "good" habits, "good" adaptations—in short of fundamentally good bio-social relations well worth distinguishing from "bad," *i.e.*, wasteful and sanguinary relations such as are usually associated with "The Struggle for Existence."

For Dr. Wallace, however, such distinctions as "illth" or "wealth" of organic relations did not exist. He was "out" to demonstrate "The Struggle for Existence," irrespective of any distinctions of appetites, although these are easily first among determinants of evolution. Could he but have seen that the "fondness" of birds and mammals for fruits is anything but accidental, but is based, in effect, upon affinities of primordial and transcendent bio-economic and bio-social importance, totally different in character from those existing between carnivores and their prey; could he but have recognised that the nobler food attraction, associated as it is with service, represents a case of Symbiosis, involving a high order of Economics, whilst the carnivorous attractions involve an opposite and inferior system of natural Economics; could he but have surmised that the apparent "intention" on the part of the fruit to be "eaten" ("devoured" is the expression he more commonly uses) by the useful animal, has to do with positive biological co-operation, and is founded upon antecedent co-operative evolution rather than upon any suddenly developed capacity of design on the

part of the plant—what a difference this would have made to his account of the evolutionary process.

On another page he tells us—again, as he thinks, in evidence of “The Struggle for Existence”—that

Flowers have been specially adapted to the kinds of insects that most abound where they grow.

He instances amongst others the gentians of the lowlands as being “adapted” to bees; those of the high alps being “adapted” only to butterflies.

From the point of view of Bio-Economics, however, this statement is very incomplete. It leaves out some essential points and slurs over the fact that we have here examples of the mutual accomodation of beings according to qualification and mutual worth. A little reflection will show that it is in the first place the bio-economic usefulness of the plant which renders possible the systematic biological traffic here concerned; and, further, that it is the quality of the insects’ service which determines their success in obtaining the boon and the far-reaching good effects of this desirable biological trade. More particularly, as was abundantly shown in the preceding pages, and must on no account be omitted in this connection, the pre-requisites of successful biological trade are these: cross-feeding and mutual forbearance. It should be expressly mentioned that the vast numbers of insects which fail as regards the aforesaid pre-requisites are *ipso facto* excluded. They do not “come in” at all. Having failed to qualify for high symbiotic service, they have no legitimate claim to the biological remuneration incidental upon such service. That the Symbiosis between flower and insect is often marked by highly specialised “adaptations”—which have an interest of their own for the mere morphologist—has its reason in special contingencies, which we are not wrong in interpreting as bio-economic contingencies. Flowers adapted to be fertilised by one class of insects, as, for example, by bees, in Wallace’s own words, stand in danger of having their nectar extracted by another class, *e.g.*, by flies, without effecting cross-fertilisation. The would-be robbers, therefore, have to be foiled; and flowers have from time to time to be modified in structure according to such (bio-economic) contingencies. We know that modifications thus interpretable frequently occur. Such modifications in effect amount to this: the flower dedicates, gives, or “adapts” itself to those animals which qualify most in Symbiosis.

The animals so excelling succeed in life and subsequently abound in numbers. It is putting the cart before the horse to attribute their success to their abundance. What is required is qualification, first and last.

The same holds good of the case of the fertilisation of flowers by birds.

Each part of the globe (says Wallace), has special groups of birds which are flower-haunters. America has the humming-birds (Trochilidæ) and the smaller group of the sugar-birds (Caerebidæ). In the Eastern tropics the sun-birds (Nectarineidæ) take the place of the humming-birds, and another small group, the flower-peckers (Dicaeidæ), assist them. In the Australian region there are also two flower-feeding groups, the meliphagidæ, or honey-suckers, and the brush-tongued lories (Trichoglossidæ).

(Again), the great extent to which insect and bird agency is necessary to flowers is well shown by the case of New Zealand. The entire country is comparatively poor in species of insects, especially in bees and butterflies which are the chief flower fertilisers; yet according to the researches of local botanists no less than one-fourth of all the flowering plants are incapable of self-fertilisation, and, therefore, wholly dependent on insect or bird agency for the continuance of the species.

All of which testifies to the vast and important rôle played in the world of life by cross-feeding animal "specialists." Although in sheer numbers the robbers and parasites may exceed, yet it is the armies of the workers which support and primarily determine evolution. On the score of the inferiority of self-fertilisation, Dr. Wallace tells us:

An immense variety of plants are habitually self-fertilised, and their numbers probably far exceed those which are habitually cross-fertilised by insects. Almost all the very small or obscure flowered plants with hermaphrodite flowers are of this kind. Most of these, however, may be insect fertilised occasionally, and may, therefore, come under the rule that no species are perpetually self-fertilised. It is now believed by some botanists that many inconspicuous and imperfect flowers, including those that are wind-fertilised, such as plantains, nettles, sedges, and grasses, do not represent primitive or undeveloped forms, but are degradations from more perfect flowers which were once adapted to insect fertilisation. In almost every order we find some plants which have become thus reduced or degraded for wind or self-fertilisation.

Again, speaking of the "Dispersal of Plants," in another place, Wallace states:

It is a very suggestive fact, that all the trees and shrubs in the Azores bear berries or small fruits which are eaten by birds; while all those which bear larger fruits, or are eaten chiefly by mammals—such as oaks, beeches, hazels, crabs, etc., are entirely wanting.

Here, owing to special circumstances, the birds have proved themselves so useful as seed carriers to certain shrubs and trees, that they have actually been able to determine the island flora in a manner more useful to themselves than to mammals, which, for several reasons, are here very sparse. This isolated phenomenon, however, by no means disproves the fact that, generally speaking, the mammalia (including man) as the higher order and representing higher values, are pre-eminent in determining the flora of our globe.

Views similar to the co-operative interpretation of evolution for which I have now for some years contended, have recently been advanced by Mr. E. Kay Robinson, well known as the Editor of "Country-Side," "Country-Side Leaflet," etc., as the following quotations will show :

Most people (says Mr. Kay Robinson) would thoughtlessly regard animals and birds which eat fruits, berries, and seeds, as the enemies of the plants which produce them, and especially would they regard the grazing animal as the enemy of the grass. Yet they would be wrong in every case. The immense genus of trees to which the apple, pear, etc., belong, undoubtedly owe their world-wide dominance to the habit of fruit-eating animals, which devour the pulp and throw away the core, or drop the seeds. In an English countryside you can locate the site of an ancient orchard by the prevalence of wild crab-apple trees in the hedges, all sown in this way. Similarly the mountain ash would still be confined to the distant valley where it originated, but for the aid of wide-ranging berry eating birds, which have distributed it broadcast in all the upland valleys of the temperate zone. When the seeds themselves, rather than berries or fruits, are eaten, the reciprocity of interest is less direct and definite ; but birds can only eat the seeds of a given plant during the short time of its harvest, and during the rest of the year they help the plants by killing insects, and even during the seed-harvest they do much good by scattering the residue of seed which they do not devour or cannot digest. For in all these cases of mutual assistance the animal (a term which, of course, includes "bird") is sustained by food which the plants produce in excess of their own requirements, and in almost all cases the animal also destroys insects, etc., which are injurious to the plants. The result is that the allies prosper side by side ; while carnivorous animals, which live by destruction, are always making their environment worse for themselves, and inevitably tend towards extinction.

Mr. Kay Robinson thinks the case of the grass and the grazing animal a particularly striking example of mutual aid. This is what he says :

In grazing, the animal eats down everything to within half-an-inch, say of the ground. This is fatal to the seedlings of all large plants, as well as to most small plants—all, that is, except a few which have some

special protection of poison, prickles, etc., or which can creep along the earth within a half-inch limit. Even of this minority most are exterminated where grazing animals are numerous, by being trampled upon or accidentally bitten off and discarded. Only the grass has, so to speak, studied the needs of the grazing animal in order to supply them to its own advantage. It produces no stem to be trampled upon or bitten through, but from its mat of fibrous roots sends up innumerable tiny ribbons of wholesome green food. When these are bitten to within half-an-inch of the ground, it pays out another half-inch of each growing ribbon in readiness for the animal's next visit. So it goes on, until the grass, in its own brief fruiting season, quickly sends up a comparatively stiff and wiry stalk with scaly and chaffy inflorescence, which the grazing animal prefers not to eat since tender blades of grass are still to be had in abundance. Thus enough grass seed survives to spread the race more widely and provide sustenance for larger herds. From this and the previous examples quoted we learn the true secret of nature in the inevitable triumph of those animal and vegetable allies which are mutually helpful to one another.

I should say that the "alliance" between grass and grazing animal does not represent a particularly high form of Symbiosis; the example, however, may serve to illustrate the application of the principle of biological remuneration, though the "remunerated" are otherwise "plant-carnivora," and *pro tanto* marked by backwardness of evolution.

Again in "Country-Side Leaflet," Jan., 1918, Mr. K. Robinson states the following:

There is no week in the country without its little harvest for the wild things, and just now it would seem as if word had been passed round that the acorns of the holm oak are really ripe at last; because scores of fat wood-pigeons are marching about under the trees in the park, gulping and choking as they go, in the effort to make room for just one more. Forty of these small acorns are only a moderate load for the wood-pigeon to cram into its crop; and indirectly it does some good by its greediness, because when it has flown home at dusk to roost in the pinewood, it is very sick and throws up, or rather throws down, some of the acorns upon the ground below. This is why young oak trees, both of the common and evergreen kinds, are always springing up under the pine trees, so that the pine wood which you knew as a boy is very often an oak wood when you revisit it as a man.

In the same way and from the same cause, the beech often succeeds the pine, because the wood-pigeon finds a surfeit of beech nuts very difficult to keep. Solitary oaks growing in the open, on the other hand, are generally the work of rooks which have buried acorns that they could not eat, and have never found them again; while it is largely to the squirrel that we are indebted for the abundant growth of oak and hazel in our woodlands. He was busy all through the autumn days, scampering about and hurriedly burying acorns and nuts, of which he probably does not discover fifty per cent. afterwards.

The case of the squirrel, as that of the grazing animals, again shows that symbiotic adaptation is by no means confined to insects and birds, as has been asserted ; but that it extends to mammals as well. True the Symbiosis between, say, honey-bee and flower seems a more perfect "adaptation" than that of the mammalia here concerned. But we may set against it the conscious Symbiosis existing between man and his food plants, which is of a high order. Evidently there are amongst all classes of organic civilisation some "professionals" who are occasionally or habitually addicted to charging exorbitant fees for their services. We have seen however, that in the event of Symbiosis at any time becoming very defective, important biological checks against transgressors came almost automatically into operation, tending to effect considerable regularisation in the economic web of life, and tending also, in the end, to restore at least a modicum of bio-economic integrity.

PART III

CHAPTER I

“ CONTRE-EVOLUTION ”

“ Le progrès de la science ne dépend pas seulement de la découverte des faits nouveaux, mais est en réalité dû à leur interprétation correcte.”
HENRI DE VARIGNY.

I HAVE already referred to Dr. René Larger's book on Degeneration, and, as I cannot insist enough on the morbidity of predaceous types, it may be useful to consider that author's testimony on the subject.

At the outset he tells us that Biologists have persistently confounded degenerative with normal characters. Although some Palæo-Zoologists have spoken of “retrogressive adaptation,” he says they have failed to recognise that they are dealing with pathological developments—a failure which, according to him, is less pardonable in Palæontologists who have had a medical training than in those who have not. Somewhat similarly I find fault with Dr. Larger's stopping short at the mere fact of pathological transmission, caused, as he thinks, by “une maladie quelconque.” This malady, I affirm, most certainly and most importantly needs specifying, and I believe it to be none other than what I have termed a “parasitic diathesis” due to nutritional transgressions and to sluggishness of life, voluntary or involuntary.

How far is Dr. Larger from such a recognition !

He approves to a certain extent of the definition of degeneration enunciated by Magnan and Legrain, which is to the effect that a constitutional diminution of psycho-physical resistance has taken place and that losses predominate, except for an occasional regeneration. Of regeneration, however, he will not hear very much, believing its rôle to be quite subordinate.

We are exultantly introduced to “Paléo-pathologie Générale, Comparée.” But the author seems as far from an appreciation of Bio-Economics as, according to him, are those whom he, not without reason, styles “Biologistes normaux,” are from appreciating Pathology. I should, therefore, be inclined to speak of

a larger class of Biologists, in which Dr. Larger still takes his place, namely that of the "Biologistes naïfs"—those who are commonly perplexed by the phenomena of disease and of degeneration because they fail to appreciate the fundamental cause of the evil, namely, non-compliance with bio-moral sanctions.

If Dr. Larger's "Paléo-Pathologie" is to supersede the spurious science of the "biologistes normaux," it must bring out what it now slurs over, the fundamental difference between Pathology and Physiology, and this regardless of all existing bias and though it involve, as it quite indispensably does, incursions into Bio-Economics and Bio-Sociology. The example of the "Biologistes normaux" should be as a warning that the complete and not the aborted view must prevail.

Scores of investigators before Dr. Larger have shown that hereditary and other diseases have in the geological past played a large part in undermining species and even genera.

Evidently the identical organismal failings and indulgences have prevailed at all periods. Such blemishes, whilst appertaining to the pathological, also appertain to the sociological order. They are, in fact, pathological largely because they are anti-social in character. Weakness has often been pleaded in depravity; but depravity, it must be owned, is also the most frequent source of weakness. As regards the antiquity of disease, Dr. Larger is not inclined to dwell too much on it, feeling that on so vast a subject as that of Palæo-Pathology he can only give a few general indications :

Trop heureux si ces quelques données peuvent servir, à de plus jeunes que moi, de point de départ pour d'autres recherches analogues aux miennes.

That Dr. Larger's chief weakness is on the sociological side becomes apparent from his definitions. No sooner has he emphasised the frequency of pathological processes as affecting not only individuals but also whole species, genera and orders, than he goes off at a tangent, telling us that "la Dégénérescence apparaît moins comme une maladie autonome proprement dite, que comme un processus contraire à l'Evolution."

When is a malady not a malady? When we fail to understand its cause. It seems a pity that Dr. Larger has chosen so grandiloquent a title as "Contre-Evolution," for it is calculated to divert the attention from those matters which would naturally interest

us most in connection with “ Paléo-anatomie pathologique,” namely as concerns the *fons et origo* of the pathology. The author, I think, would have done better to take up the threads left by pre-evolutionary French writers such as Morel, for instance, of whom he says :

Pour lui, la Dégénérescence n'était autre chose qu'une déviation malade d'un type primitif

or by Isidore Geoffroy Saint-Hilaire who

admettait la transmission héréditaire, sous l'influence d'une “ diathèse malformatrice.”

The fact that, as Magnan has stated, degeneration is destructive of evolution, need by no means be interpreted as proving a “ Contre-Evolution.” Degeneration is merely, as an evil, impeding evolution. To Magnan, Dr. Larger pays a high tribute, for having by his wording suggested to him the title of “ Contre-Evolution.” But Magnan's words are clearly suggestive of something much more sane than “ Contre-Evolution,” namely, of the simple truth that there is, and always has been, a wide prevalence of disease, eating canker-like into the very heart of the organism and impeding progress. According to Magnan, degeneration is a morbid state of the organism, showing a striking imperfection of functions compared to the state of progenitors.

Bien plus, cet état morbide constitutionnel s'aggrave progressivement, et, de même que la dégénération d'un tissu précède sa disparition, sa mort, de même la dégénération de l'individu précède son anéantissement dans son espèce.

In other words, “ function ” has deteriorated, as a result of which serious deficiencies arise. The magnitude of the evil, of the “ diathesis ” thus ensuing, is proportional to the deficiency of “ function ”—more particularly bio-economic function, I should add. The progress of the race is self-impered. The race does not counter-evolve in order to die of a premature death. It fails to evolve satisfactorily. *Voilà tout*. Magnan might have added to his definition that if anything avails towards death rather than towards life, it ceases *pro tanto* to be evolutionary, *i.e.*, progressive, and becomes pathological, *i.e.*, merely negative or chaotic.* We have seen that Magnan does not overlook the psycho-physical factor, which is as a hint that he, at any rate, contrary to Dr. Larger's view, regarded degeneration as “ une maladie autonome proprement dite.”

* Dr. Larger himself says on page 86 “ ce qui caractérise souvent la Dégénérescence, c'est l'absence de règle fixe,” *i.e.*, absence of Law and Government.

If Dr. Larger had not contemptuously brushed aside autonomy and regeneration and instead made a kind of entity of "Contre-Evolution," he might have seen that there is no inherent necessity of degeneration or of loss of plasticity, be the organism never so high in the scale of evolution. Instead of which we get the ludicrous statement on p. 26 with regard to man, that

De même que tous les animaux supérieurs, il a perdu toute plasticité et ne peut plus dès lors que dégénérer et disparaître.

and, further, p. 27 that :

Plus l'animal est élevé dans la hiérarchie zoologique, moins il est plastique et plus les régressions deviennent dégénératives.

The author's reasoning with regard to degeneration seems to be this : these things are, therefore they must be. But, as there is no inherent necessity for a highly evolved animal to be divorced from Symbiosis, so there is no reason why it should lose the plasticity requisite for further progress. Inasmuch as man remains a symbiotic cross-feeder, he has infinite chances of survival.

It seems never to have occurred to Dr. Larger that plasticity and progress on the one hand, and stagnancy and pathology on the other, are dependent upon sociological factors. Although he is not an adherent of Natural Selection, his own theory has this in common with it, that it tends by a facile generalisation to force sociological factors into the background until they are nearly lost to vision, with results altogether deplorable.

I agree with the author when he states that there is

Dégénérescence, c'est-à-dire, maladie, dès l'instant où la défense de l'organisme se trouve affaiblie par une cause quelconque.

He is getting, however, somewhat mixed when he continues :

Peu lui (to the Pathologist) importe qu'il y ait perte ou gain des parties, c'est-à-dire, régression ou progression.

If the defence of the organism is enfeebled, there is sure to arise a loss, and such loss is serious. More especially must this follow where there is an abiding cause, such as in-feeding, behind the enfeeblement. On no account must we allow ourselves to be deceived into conceiving of dubious pathological additions—transformations conforming to the existing pitch of diathesis—as progressive features. I read Dr. Larger's statement, therefore, as a counsel of despair, his diagnosis being still too incomplete to distinguish in many cases between "régression" and "progression," between pathological and physiological additions.

He is merely able to certify some rather acute cases of " régression " with the aid of his anatomical stigmata. For these criteria we owe him thanks ; but I think one must still apply to him the same criticism which he applies to Cope, who, according to him :

en dépit de son grand mérite par ailleurs, n'a fait que créer une confusion fâcheuse en détournant complètement le terme de Dégénérescence de son sens exclusivement pathologique—qui est le vrai (ce qu'il avait le droit d'ignorer. Cope, en effet, n'était pas médecin)—pour ne lui donner, au contraire, qu'un sens exclusivement évolutif auquel ce même terme ne saurait prétendre, la Dégénérescence étant, par sa nature, destructive de toute évolution normale.

This is well said ; but has not Dr. Larger fallen a victim to the same temptation ? Is he not giving to a merely " destructive " and chaotic agency a sense still too " évolutif," and does not this involve him in difficulties similar to those of the " Biologistes normaux " ? Let us see.

On p. 33 we find him grappling with the perennial problem of Parasitism, and this is what he says :

Ces régressions, en effet, si graves soient-elles au point de vue morphologique, ne présentent aucun des caractères de la véritable Dégénérescence. Le plus essentiel de tous leur fait défaut, celui qui, nous venons de le voir, est compris dans la définition même de la Dégénérescence, à savoir : la stérilité et l'extinction de la descendance. Loin d'être frappés de stérilité, ces animaux parasites sont, au contraire, d'une fécondité incomparable... Les régressions, purement morphologiques, des parasites, se réduisent donc à de simples phénomènes d'adaptation. C'est, si l'on veut, de la Dégradation, mais non pas de la Dégénérescence ! C'en est même tout juste le contraire, parce que, loin de diminuer les moyens de défense de l'organisme, ces régressions les augmentent. Car l'atrophie par non usage des parties, constitue une adaptation parfaite à la vie parasitaire ou de fixation. C'est ce que le botaniste Korschinsky a très justement appelé : l'adaptation régressive, ainsi que nous l'avons dit.

Here then we have a medical man who cannot distinguish between morbid and wholesome reproduction, who sees in excessive multiplication a proof of normality, who, with the " Biologistes normaux," classes parasites amongst the most genuinely successful organisms. Morphologically, as he admits, the case of parasites is serious ; sociologically, as he omits, their case is even worse. Yet, we are asked to consider such degradation as the very opposite of " Dégénérescence." What monstrous aberration of the human mind ! Parasitism, as the author admits, frequently gives rise to Paedogenesis, *i.e.*, precocious reproduction, but we are asked not to regard this as pathological or as counteracting

the survival of the species, though, of course, obviously increasingly curtailing adult existence. When is a disease not a disease? When it is an "adaptation." But, it must be "une adaptation parfaite," Dr. Larger would probably add. Even parasites, however, scarcely begin their career of profligacy with "adaptations parfaites." Nor are these parasitic adaptations "parfaites," as the author himself is obliged to admit. This is how he expresses his scruples:

Toutefois, si l'on n'a pas raison d'appeler les parasites des Dégénérés, ce serait peut-être exagéré de dire qu'ils sont absolument normaux. Il est certain, en effet, que si le Parasitisme, n'est pas la Dégénérescence, il est non moins incontestable qu'il y prépare le terrain pour l'avenir.

If Parasitism is not quite normal, after all, what kind of disease or malady does it represent?

From the acknowledgment of Parasitism as a preparatory stage of "Dégénérescence," it should not be too great a step to the recognition that a lapse in the parasitic direction constitutes quite usually the preparation for pathological states. It is merely a matter of discerning the roots of disease and of recognising a disease as such long before it has become acute or malignant. Unable to deal adequately with Parasitism, Dr. Larger finally places it in the borderland between normal evolution and "Contre-Evolution," and, having got it thus safely out of the way, lets well alone. The thought of "mis-adaptation" has apparently never occurred to him. He postulates "Inadaptation" (in the end) as distinguished from "Adaptation" (in the beginning), and he has a convenient way of arriving at the one by the other by the further postulation of "Semi-adaptation," a kind of intermediary stage "où les mutations sont les unes adaptatives et les autres inadaptatives, sur le même sujet"—in fact "des cas mixtes," where "l'adaptation générale, vu la solidarité des organes" becomes deficient.

Is this not a case of imperfect function where the autonomy of the organism is at fault, such as it is in all cases where the organism yields to temptations apt to determine it in the parasitic direction? But the author arrives at his "mutations semi-adaptatives" without the invocation of autonomy, a factor which, according to the prevailing fashion in Biology, is burked as much as possible, or referred to usually with contemptuous remarks concerning the metaphysical eyewater of the user of the term. If we consider the following passage, it becomes clear

that what is really implied could be better stated by saying that there frequently exist amongst organisms different degrees of the parasitic diathesis—different that is, according to the varying transgressions and the different compatibilities of each case.

This is what we are told :

Or, ces mutations semi-adaptatives, restant toujours dans le domaine de la dégénérescence, c'est-à-dire de la contre-évolution, doivent être placées, en conséquence, au même rang que les inadaptatives ou contre-évolutives complètes. Ce n'est en effet entre elles, qu'affaire de proportions, et l'animal pour n'être que dégénéré faiblement, n'en reste pas moins " un dégénéré." De telle sorte qu'au lieu de succomber de suite et d'être stérilisé, lui et sa descendance, il arrive que cette dernière est, dans le principe, seulement diminuée dans sa natalité et sa variabilité.

In other words, there are inceptional stages and gradations in the respective " misère." Must we not search for the root of the evil ? But the author instead goes off into Geology, telling us that :

Les choses peuvent durer longtemps ainsi—et l'on sait ce que " longtemps " veut dire quand il s'agit de périodes géologiques ! Dans le cours de ces dernières, les conditions peuvent changer et changent presque forcément. Mais les descendants légèrement atteints, il est vrai, par la dégénérescence, quoique cependant diminués dans leur vitalité, se défendent mal, partant, s'adaptent aussi de plus en plus mal. Ils en arrivent ainsi à subir *progressivement* la dégénérescence complète et finalement disparaissent.

If the organisms defend themselves badly, this is because they had previously comported themselves badly. This, surely, is the common-sense of the matter ; and it would much simplify Biology to say so, and to make a thorough study of behaviour instead of inventing ever new grandiloquent terms to suit misty and fanciful postulations.

" You must always think of ' semi-adaptation,' " says Dr. Larger, " in order to understand counter-evolution." So much the worse for " counter-evolution," I should say ; for " semi-adaptation " is semi-nonsense.

How well the author can reason with those despised " Biologistes normaux," who fail to distinguish between mutations that are useful and those that are injurious, may be seen from the following :

Tel est le problème que se sont posé en vain tous les paléontologistes, à commencer par Kowalevsky et Cope lui-même. Car s'ils sont tous d'accord pour admettre l'existence des deux catégories de mutations, cette entente cesse parfois d'exister lorsqu' il s'agit de distinguer celles qui sont " utiles " d'avec celles qui sont " nuisibles." Certains biologistes, pour

se tirer d'embarras, ont imaginé en outre une troisième catégorie de mutations : les mutations "indifférentes." Comme si quoi que ce soit pouvait être jamais *indifférent* dans la nature où tout a sa raison d'être. Or, cette raison d'être, nous pouvons parfois ne pas la distinguer ; mais la nier, non point !

The case for Nature could scarcely be better stated, were it not that the question of "usefulness" is the great stumbling block in Biology. Could Dr. Larger but bring himself to realise that there exists a sociological, *i.e.*, economic and moral "raison d'être" in Nature, and that such "raison d'être" lies behind the phenomena to which he calls attention. Towards the distinction of "useful" from "injurious" mutations he can guide us but little more than the "Biologistes-normaux." According to him, it is the constant aim of Nature, not only to maintain, but also incessantly to improve the means of defence in the organism. He does not, however, stoop to tell us how this noble end is attained. He takes the fact for granted, and, Nature's high aim being somehow fulfilled,

Il y a adaptation et l'animal continue d'évoluer normalement vers des adaptations nouvelles. Dans le cas contraire, il y a non adaptation, ou inadaptation et l'être quel qu'il soit, animal ou végétal, dégénère et disparaît. Il ne peut rester stationnaire, à moins d'avoir une organisation très simple, indifférente jusqu' à un certain point aux influences internes et externes.

In other words, *qui non proficit, deficit*, which is, after all, a sociological truth. "Adaptation," according to this view, is born of the noble intents of Nature, but it remains to be seen what it is that confers the sanction of Nature upon one "adaptation" more than another. Dr. Larger is far from realising that normal adaptation is that which accords with normal behaviour, *i.e.*, such as is calculated by its other-regarding value sufficiently to compensate Nature for her pains. Yet what simpler or better explanation than the sociological is there to account for the fact of the simultaneous and correlated progress of closely interdependent beings which constitutes evolution ? It follows from such a view that degeneration is to be regarded as the result of long-continued misuse turning organic wealth into "illth." Failing such common-sense view, Dr. Larger feels constrained to make the sweeping assertion that "tout s'use, tout dégénère dans la nature," as though use *per se* entailed degeneration, which, of course, is not true. We may say, on the contrary, that the more right use, the less degeneration.

As I have throughout strongly insisted on the distinction between cross- and in-feeding, it is significant to learn, that, on Dr. Larger's diagnosis, the (cross-feeding) *Equidae* have not appreciably degenerated :

Si l'on considère l'adaptation à la course dans le phylum des Équidés, on observe, outre les mutations régressives des membres, des modifications corrélatives avantageuses de la dentition et du crâne, du cerveau, des poumons, du cœur, etc. L'essentiel est que, Régressives ou Progressives, les mutations non seulement n'entraînent pas à leur suite une diminution des moyens de défense de l'organisme, mais contribuent au contraire à les améliorer dans leur ensemble. Tel est précisément le cas des *Équidés actuels* qui, pour cette unique raison, n'ont pas dégénéré. Les Équidés, en effet, non seulement ne présentent aucun stigmatte appréciable de dégénérescence ; mais sont, au contraire, merveilleusement adaptés à la course.

But after all that has been said on the subject, we may be sure that the far-reaching correlations of the cross-feeding habit have had more to do with the general beneficence of modifications in the *Equidae* than their running propensities, although these, of course, implied healthy exercise.

When we find that the *ensemble* of parts has gained in the organism, we may justly conclude that the organism has not been “hors de Symbiose” as regards feeding. Who will deny, moreover, that the physiological “means of defence” are derived to a large extent from the symbiotic environment, and that the supply of the respective potencies is the more assured and the more regular, the more there is of symbiotic behaviour, of symbiotic disposition, and of symbiotic moderation ? In my *Evolution by Co-operation*, I have emphasised the fact that the horse is comparatively modest amongst grazing animals, and that young foals do not gorge themselves with milk as calves do. I have there also remarked that I see the explanation of Cope's second law in the survival of legitimate bio-economic behaviour. What is known as Cope's second law is that of non-specialisation. It states that “organic types which are not specialised alone are capable of an ulterior evolution.”

Those animals, says Cope, which have attained excessive specialisation, have lost their plasticity, their adaptive faculty, and are, therefore, destined to perish with a change of environment. This, says Dr. Larger, is but a statement of facts :

Sans pouvoir les expliquer,—sans même y essayer, car la notion exacte de la vraie Dégénérescence leur (Cope and Dollo) fait défaut à tous deux, comme d'ailleurs à tous les Biologistes-normaux.

But does he really explain very much with "Dégénérescence"? His reference to the "means of defence" as the "unique" cause of success, without telling us, however, wherein consists the real strength of resistance in a species, is after all, but a statement of facts—a way of begging the true question. And if the "marvellous adaptation" for running is to be considered as the antithesis of degeneration, this rather contradicts the previous generalisation that in Nature every use unfailingly involves degeneration. I agree with Dr. Larger's diagnosis as far as it goes, for instance, when he says: "*le Gigantisme Acroméganique* est toujours une tare dégénérative grave."

I view the phenomenon, indeed, as so grave as to consider it as but the last link in a long chain of a pathological process due to trespasses against the bio-moral order of the world.

We are told that the Pterosaurians, which disappeared suddenly with *Pteranodon*, "*sont acroméganiques tout à leur origine*," which is merely a conjecture, for we know nothing about origins. The author, however, corrects himself by saying that they were

Semi-dégénérés par avance, mal ou insuffisamment adaptables, par conséquent, ils étaient aussi mal armés pour se défendre des maladies et de toutes les causes de destruction. Demi-dégénérés dès le principe, ils restent des demi-adaptés jusqu' à la fin.

But whence their initial semi-degeneration? Did they not spring from erstwhile normal ancestors? It is futile to trace degeneration down to semi-degeneration and to leave the matter there. Elsewhere Dr. Larger himself protests against the practice of placing "*en tête d'un Phylum, au titre ancestral, des animaux dégénérés*," exclaiming that "*c'est purement et simplement un non-sens*." I would enter a similar demurrer to his placing at the beginning of a race a semi-degenerate.

Darwin at least hinted that carnivora may improve their chances of life by becoming less carnivorous, and he further stated that liability to extinction may be due to "lack of improvement according to the principle of the all-important relations of organism to organism in the struggle for life." But there is scarcely an allusion to such (semi-sociological) considerations in Dr. Larger's work. He only just notes that the difference between Pterosaurians and Birds consisted in the fact that the former were cold-blooded animals, whilst the latter are warm-blooded

and that, for this reason probably, the former were the inferior aviators. But such physiological differences, I affirm, are importantly connected with differences of food and Symbiosis, and the distinctions require to be clearly established. We may feel sure that Symbiosis, and Symbiosis alone, conduces to that state and condition of the blood which are most favourable to progress. More will be said on this subject in a subsequent chapter.

We are further told :

D'autre part, les *Oiseaux* présentent, à tous les points de vue de l'Aviation, un contraste saisissant avec les *Ptérosauriens*. Ils ont sans doute tous deux la même origine reptilienne ; mais tandis que l'un marque le pas et reste jusqu' à la fin un reptile plus ou moins maladroit au vol, l'autre s'élève rapidement au rang supérieur d'oiseau et atteint jusqu' à ce degré d'aviation parfaite—c'est le cas de le dire ! —qui nous frappe d'admiration chez le *Martinet* et le *Condor*. Le Ptérosaure traîne, depuis sa naissance, le boulet de la Dégénérescence qui le retient au sol et finit par le tuer ; tandis que l'oiseau, né et resté sans la moindre tare dégénérative, a été trouvé pour la première fois dans les schistes Kimmeridgiens d'Eichstaedt, l'oiseau, dis-je, ne tarde pas à s'adapter merveilleusement *intus et extra*, à la vie de l'aviateur et, enfin, dure plus que jamais !

But where is there a mention of the most important adaptation the ancestors of the birds have ever made, namely, the adaptation to Symbiosis with the plants, which has first rendered evolutionary success possible ? It is over-looked, just as was the case of cross-feeding on the part of the horse and its ancestors.

We know that the birds, like the insects, have been of great bio-economic usefulness through the dispersal of plants, and this inasmuch as they were mainly cross-feeders. We may conclude that the leading physiological adaptation of the birds, in virtue of which they excelled over the reptiles, was a widely useful adaptation ; and that it was, hence, from a symbiotic source that they originally obtained the wherewithal for favourable adaptations in many important directions. Subsequently, in so far as many birds ceased to be symbiotic cross-feeders, and, like large numbers of the Pterodactyles, became increasingly in-feeders—beasts of prey—they tended to lose the power of making favourable adaptations. Although with the birds of prey the adaptation for flying is stimulated to the highest pitch, such stimulation is not free from morbidity. The stimulating diet of an in-feeding species may allow of a temporary acceleration of many life processes and even of “specialisations” in particular directions—the principle of compensation lending itself to numerous

applications—but such stimulations attended as they are by losses of other, milder, yet more vital stimulations, are followed by sudden and often startling exhaustion of the species. The balance of the account in the end shows a loss. Something of the sort has happened to the birds as a class, for we are told :

Si rapide a été leur évolution que, dans les couches mêmes où disparaissent sans retour, les derniers Ptérosauriens, les *Pteranodontités*, on rencontre des Oiseaux tellement différenciés que certains d'entre eux, tel *Hesperornis regalis*, Marsh, en avaient déjà perdu la faculté de voler.

To say that the heavy, flightless, and wingless *Hesperornis* was highly differentiated, is putting rather a peculiar complexion on the case. We need to know the physiological reason for the degeneration of the bird, and the reason is this : in-feeding together with its anatomical correlations, leading to inferior adaptations. In bio-economic terms, the bird had become divorced from the leading (symbiotic) adaptation of its order and had to pay the penalty by losses in many directions. As I have emphasised in my *Evolution by Co-operation*, the bird was a gigantic diver, allied to the grebes of to-day. The set-back of the legs, and the large knee-cap and enameled crest seem to have rendered an erect position impossible. The explanation of the Anatomy of the bird is to be found in its feeding habits.

As Ch. Depéret surmised, the rapidity of evolution of a group is in inverse ratio to its longevity. He should have added that longevity depends in the first place upon cross-feeding. The class of the birds includes many excellent examples showing that cross-feeding species excel in longevity.

Of the *Ratitae*, the name applied by Huxley to the order of flightless birds of old, in which the sternum is destitute of the prominent ridge or keel, to which the large pectoral muscles are attached, we are told that "leur inadaptation au vol 'par défaut d'usage' entraîne leur Dégénérescence," and we get an allusion to Owen's remark that Nature presents no greater anomaly than a bird which cannot fly. "Cet oiseau déchu, c'est le *Ratite*." But, surely, we have here "misuse," over and above "disuse," and it is not enough merely to continue "Mais qui dit *Anomalie*, dit le plus souvent Dégénérescence." Instead we should be shown that the transformations, or "mutations," based upon in-feeding, never have the sanction of Nature, and that only cross-feeding can provide the physiological groundwork fit for abiding transformations.

The numerous " dystrophies dégénératives," cited by the author, are without exception the usual concomitants of the parasitic diathesis. For instance :

Le *Casoar à casque* présente de plus un stigmate concomitant de Dégénérescence, une *Exencéphale*, ou tumeur cérébrale congénitale dont j'ai démontré jadis la nature exclusivement tératologique. Il en est de même de la *poule de Houdan*. La poule domestique, en effet, est en train de subir un commencement de Dégénérescence analogue à celle des Ratites. Sa température, ainsi que je l'ai vérifiée, s'est abaissée, comme celle du Ratite, de 3° à 4° 5, selon les espèces ou variétés et par rapport à celle des *oiseaux volants*.

The " misère " of these birds is none other than that of creatures divorced from Symbiosis, be it in Nature or in Domestication.

The *Ratitae* (or *Cursores*, or Runners, comprising the Ostriches, Rheas, Cassowaries, Emus, and the singular *Apteryx* of New Zealand) represent an artificial assemblage, and, according to Dr. H. Gadow, a convergence. But, says Dr. Larger, it is entirely a case of " convergence dégénérative." I quite agree ; but I would emphasise the striking convergence of anti-biotic behaviour, which is involved.

The same reasoning as is applicable to the *Ratitae*, according to the author, also applies to the case of the *Edentata* :

Les *Edentés* nous offrent l'exemple d'un groupe simplement artificiel, plus accusé encore que ne le sont les Ratites. Car si chez ces derniers, il existe encore une parenté spécifique réelle avec les Carinates, chez les *Edentés*, cette parenté unique disparaît elle-même et les stigmates dégénératifs les plus variés constituent le seul lien de convergence pathologique qui ait pu servir à les unir les uns aux autres.

Amongst the *Edentata* are comprised some herbivorous and some insectivorous creatures. The herbivorous, however, have, no doubt, similar to the elephants, long become " plant-carnivora," which accounts for their slow degeneration. Their ancestors at one time were normal cross-feeding species, though the traces of such ancestry be lost in the dim past. That the in-feeding, *i.e.*, purely insectivorous *Edentata* have degenerated cannot cause the least surprise.

According to Dr. Larger's diagnosis, the chief acromegalic character in the *Ratitae* are to be found in the vertebrae, which are extremely osteoporose, although the other bones of the skeleton, too, according to him, are usually similarly affected. The beginning of such osteoporosis has even been traced in our

hens, some of which are losing the power of flight. Of the skeleton of the gigantic *Dinornis maximus* from New Zealand, we are told :

A première vue, je fus frappé de l'identité complète que présentent les os de ce squelette, avec ceux du Géant acroméganique humain actuel du Muséum de Paris. Ce sont exactement, en effet, les mêmes innombrables cellules osseuses, constituant un tissu spongieux à mailles tantôt fines, tantôt larges et à parois très minces, ayant envahi les os entièrement et ne laissant à leur surface qu'une coque fort mince de tissu compact où s'enfoncerait le doigt comme dans une motte de beurre, si on y exerçait la moindre pression ! L'identité de structure en est frappante et me paraît tout à fait incontestable, je le répète. Cette ostéoporose atteint notamment les vertèbres de l'homme acroméganique et celles du *Dinornis*. L'exagération de la même dysostose ostéoporose conduit aux grandes cavités osseuses qui se voient, on le sait, sur les vertèbres des *Dinosauriens* et j'ajoute, des *Ptérosauriens* dont nous venons de parler. Elle y affecte, chez les uns et les autres, la forme et le volume de véritables sinus d'où le nom de, "*Sinusomégalie*" que j'ai donné à cette forme de dysostose acroméganique, par analogie avec celle qui s'observe sur certains os du crâne de l'homme acroméganique actuel.

Here then we have a picture of the anatomical bad effects engendered by a parasitic diathesis in man and beast, past or present. Up till now, Palæontologists have not been able to provide "aucune explication raisonnable" of the phenomena. Some have seen in the "*sinusomégalie vertébrale*" merely an adaptation to flight, calling it "*pneumatisme osseux*," analogous to that of the birds. But Dr. Larger will have none of it :

On ne tient nul compte par là de ce fait que l'oiseau volant lui-même n'a jamais présenté de vertèbres pneumatiques ! Et que ses vertèbres ne deviennent poreuses ou soi-disant pneumatiques, que juste au moment même, où, passé à l'état de Ratite, il cesse définitivement de voler ! Au surplus, personne, que je sache, n'a jamais poussé la fantaisie jusqu' à prétendre que les *Dinosauriens* fussent des animaux doués de la faculté du vol !

In the *Dinosaurians*, then, "*dysostoses ostéoporeuses ou sinuso-méganiques*" are to be regarded purely as manifestations of Acromegaly. As in the case of the *Ratita* and *Edentata*, so in that of the "*Thalassothériens*" (*Sirenia*, *Cetacea*, etc.), which have become "*adapted*," from an erstwhile terrestrial, to an aquatic life, I do not agree with Dr. Larger that their "*Régressions adaptatives*" are altogether "*automatiques*," but I submit that they are largely due to inferior feeding habits.

Some of the stigmata adduced by the author are to be met with more widely than he evidently thinks, especially if we study their milder forms. Without becoming "*pisciformes*,"

like the "Thalassothériens," many animals, including men, are to be met with in which "la tête fait, de plus en plus, suite au tronc, sans démarcation." The result is brought about by bad feeding habits, and wherever we detect stigmata of this kind, even in the more general appearance of the organism, there, we must conclude, disease is present.

We are told that :

les Thalassothériens de pleine mer (*Baleine*, *Cachalot*, etc.), sont plus dégénérés que ceux qui, ne quittant pas les côtes et ayant conservé—c'est le cas de le dire—*un pied-à-terre*, vivent et se reproduisent en partie sur le sol, comme les *Siréniens* et les *Pinnipèdes*.

It should surely be added that the *Sirenia* have conserved their cross-feeding habits, and that the *Pinnipedia* have in all probability only comparatively late in their history become converted to in-feeding habits, their glands thus retaining considerable capacities of manufacturing useful secretions even from second-hand food.

The chief "stigmaté" of the *Cetacea*, according to Dr. Larger, consists in "asymétries cranio-faciales," although, here too, we meet with osteoporosis, or "hypertrophie spongieuse des os," or even with "Osteosclerosis" (*Os craniens éburnés*)—"ce qui réduit à néant l'argument unique tiré de la flottabilité par allègement." That the "Biologistes normaux" cannot account for numerous features otherwise than by classing them as "useful in combat," does not deter Dr. Larger from classing them as pathological, which, in truth, they very often are. I fully agree with him when he says :

Dans ces cas, comme dans beaucoup d'autres, je le répète, la Nature fait effort pour profiter de l'existence d'une lésion pathologique, en la transformant, tant bien que mal, en une mutation plus ou moins utile. Mais, en vérité, on n'a pas le droit de dire que c'est prémédité et normal de sa part ; et n'est-ce pas véritablement forcer la note que d'y voir une mutation proprement adaptative ?

As far as possible, *i.e.*, as far as the frailty of life permits, Nature is for ever trying to make the best of a "bad job," and this fact should not be lost sight of, if we are to understand the nature of the condominium of good and bad characters in a species. In point of interpretation, however, neither "adaptation, nor "mutation," nor "struggle" would satisfy me, seeing that all these terms are employed without a bio-economic standard of usefulness or normality.

An interesting problem arises in connection with the "Pachyostose" of the Sirenians :

D'après le Prof. Abel, en effet, cette pachyostose constituerait "*une cuirasse interne, une défense protectrice contre les fractures, et serait le résultat de l'action des flots sur les os des Siréniens.*"

This explanation does not satisfy Dr. Larger, who demurs :

Mais pourquoi, seuls de tous les Thalassothériens, les *Siréniens* auraient-ils besoin de cette fameuse *cuirasse interne* ? Et encore : l'action des flots n'est-elle donc pas la même pour tous ?

But it is all not so much a question of what is necessary or expeditious, but rather a matter of what the physiological economy of the organism can afford—what Nature, with the means thus offered her, can afford to do by way of making the best of "a bad job"—all of which depends very largely upon feeding habits past and present.

In every one of my books I have emphasised the fact that loss of symmetry is a grave symptom of Pathogenesis, and I find myself in complete agreement with Dr. Larger when he says that :

l'Asymétrie cranio-faciale est un stigmate dégénératif grave, incontestable et incontesté.

This asymmetry, we learn, is a feature amongst the *Cetacea*, and it occurs amongst men—always a more or less grave symptom of disease. I also agree with the author that man must serve us as the prototype in the study of degeneration. And here is perhaps the place to mention that Dr. J. Bland Sutton, in his *Evolution and Disease*, after a fairly wide study of the zoological distribution of disease, reaches the conclusion that many diseases, supposed to be distinct in man and the lower animals, will one day be found to depend upon the same cause—which cause I believe to be none other than the parasitic diathesis.

In speaking "de la Dégénérescence en général," Dr. Larger expresses the view that the

loi de solidarité ou de corrélation des Stigmates de la Dégénérescence n'est, par le fait, que l'application à la pathologie de "la loi de Corrélation des caractères (normaux) de Cuvier."

This deserves mention because "correlation" is admittedly a most important matter—one, moreover, which has not hitherto had paid to it the attention it deserves. I would add that in order to arrive at a full comprehension of the subject, it is indispensable to take bio-economic correlation duly into account.

But Dr. Larger is still far too exclusively “teratologiste,” and his endeavour to fall into line with, or even to improve upon, “la manière large” “de concevoir la Dégénérescence, manière inaugurée par Charles Féré,” must still be pronounced a failure. What on special occasions he has to say of the solidarity of the organs and the resulting possibilities of pathological correlations, must be extended, *mutatis mutandis*, to the idea of the solidarity of all life. Neither can it be overlooked that the degeneration of the higher organisms presents a case of a *corruptio optimi pessima*.

I quote, not without sympathy, the author's further remark :

Je discerne déjà ce reproche que j'ai souvent entendu résonner à mes oreilles : “*Mais alors tout le monde est dégénéré !*”—Mais parfaitement ! Dans les races trop civilisées du moins, ou trop spécialisées, comme on dit en Paléontologie—peu de familles, en effet, sont absolument normales. Et plus ces familles sont cultivées et plus elles comptent de dégénérés ! Et voilà pourquoi, étant toutes plus ou moins “prédisposées,” elles finissent par disparaître pour faire place à des Races indemnes de Dégénérescence. N'est-ce pas ce que l'Histoire, d'une part, et la Paléontologie, de l'autre, démontrent de la manière la plus incontestable ?

There existed a fair consensus of opinion amongst ancient philosophers that the chief cause of the decline of races was excess :

Multo plures satietas quam fames perdidit viros.

And this, in my opinion, is fully borne out by the study of Biology, as also of Palæontology. Whilst predisposition, with me, begins with a divorce from Symbiosis, with Dr. Larger it begins only when such divorce has, after ages it may be, produced grave anatomical blemishes. I wonder whence, in his opinion, spring the “races indemnes de Dégénérescence,” and what, according to him, would have to be the qualification of a progenitor fertile in normal offspring ? The mere absence of “stigmata,” surely, is not enough, and tells us very little about the physiological qualifications required. Nor is it enough to say that : la plasticité s'accuse progressivement en remontant vers l'origine du phylum.” What we want to know is this : wherein consists normal specialisation ? The question why the puny mammalia have scarcely degenerated, involves the author with his axiom that “tout dégénère dans la nature” in some difficulties. He thinks the organisation in this case has remained primitive, the organisms having preserved their general characters

without "excès de spécialisation portant sur les organes essentiels à la vie."

This, however, is not, as he thinks, a statement of cause, but one of facts only, without any explanation of the facts whatsoever. I have shown in my *Evolution by Co-operation* that in many cases the differences of size are quite obviously connected with differences of diet, and I have there also traced pronounced sexual dimorphism to one and the same source, namely the parasitic diathesis (p. 78). Dr. Larger concedes that the way of life may have contributed to the success of the punier races. They are, he says, generally omnivorous, or feed upon animals and plants which exist in all seasons, wherefore, he thinks, they are well adapted to the changes of climate [*i.e.*, they are tolerably cross-feeders and many entirely so]. Besides, he continues, many bury themselves during the unfavourable season and manage to keep their nutrition suspended during hibernation [*i.e.*, they practise moderation, thus achieving regeneration and rejuvenescence—matters altogether under-estimated by Dr. Larger]. He further suggests that if they do not counter-evolve (degenerate) this is because they did not in the first place evolve either, which is evidently special pleading. Finally, he adduces his supposed strongest reason: as these types do not show any "stigmaté de Dégénérescence," it must be that they have preserved intact their reproductive function—which, again, I demur, is no explanation, but only a surmise of facts. But the author eventually finds a way out of the difficulty by dismissing the argument altogether:

or la petitesse de la taille est un fait qui n'explique absolument rien.

He is on safer ground when he tells us:

le Gigantisme se rencontre, en effet, chez tous, quels qu'ils soient: Vertébrés ou Invertébrés, depuis le Gorille jusqu' aux Foraminifères. Sa constance à la fin de presque toutes les espèces, tous les genres, familles, classes et embranchements, est même telle, que le Gigantisme des animaux actuels et fossiles est devenu incontestablement la question capitale de la Paléopathologie générale comparée et, partant, dans la recherche des causes de l'Extinction des groupes quels qu'ils soient.

All flesh is apt to pervert its way.

As regards, once more, the cause of "Dégénérescence," in trying to be more explicit than at first, when he referred to "maladie quelconque," the author tells us that:

ce qui est incontestable, c'est qu'elle désigne une maladie constitutionnelle, c'est-à-dire générale, dont la cause intime est encore indéterminée,

ce qui explique certaines divergences. Et s'il est permis d'émettre, à cet égard, une hypothèse, il semblerait qu'elle soit due à une *altération protoplasmique*. Mais la chimie seule pourra faire de cette hypothèse une réalité, le jour où elle se trouvera en mesure d'analyser et de synthétiser les albuminoïdes. Une infinité de phénomènes tant physiologiques que pathologiques s'expliqueront sans doute ainsi.

This is putting us off to the Greek Kalends. My further comment is that "altération protoplasmique" signifies above all "altération symbiotique," both physiologically and biologically speaking. Not Chemistry, but Bio-Economics can supply the solution of the problem. We have seen that the best conception of protoplasm is that of a partnership subject to "sociological" laws, both "domestic" and biological. Sociological factors we have indeed found to be the chief determinants of protoplasmic success, and we have also concluded that the more there is of Symbiosis, the more there exists of healthiness, of division of labour and of resulting support, sanction, longevity, and plasticity of life. That the protoplasm is largely determined by biological factors, is implied by Dr. Larger's own remark that microbic intoxication must be held responsible for many pathological changes—when it remains to be seen, however, in how far the organism by its own transgression provides the soil for infection. When the protoplasm is thus affected, according to the author, it loses "progressivement," all its properties, and the organism becomes "un bouillon de culture." We are told in capital letters :

C'est, en effet, la mauvaise qualité du terrain—il faut y insister —qui caractérise le dégénéré.

In other words, the soil is more important than the microbe. When the "soil" is badly "fertilised" by inappropriate nutrition, infection and degeneration set in. *Ubi uber, ibi tuber*. It is now quite evident that the following passage merely requires interpretation in terms of co-operation instead of struggle in order to give a totally different complexion to "Contre-Evolution" :

Tout être organisé, quelqu'il soit, vit sans cesse au milieu d'une infinité de microbes saprophytes et pathogènes. Ils pullulent à la fois dans l'atmosphère qui l'entoure, à la surface de son corps et dans toutes ses cavités naturelles en contact avec le milieu extérieur. Les épithéliums de la peau et des muqueuses ont pour fonction principale de lutter sans cesse contre la pénétration de ces microbes et de leurs toxines dans les tissus. Ceux-ci sont envahis dès l'instant où ces épithéliums, altérés dans leur nutrition, opposent un obstacle insuffisant à l'invasion, laquelle devient

complète au moment de la mort. Mais les moyens de défense de l'organisme vont plus loin encore et le sang renferme les *phagocytes*, ou fabrique par les glandes endocrines, les *anticorps* et autres antitoxines pour détruire les microbes ou neutraliser les poisons qui ont franchi en fraude les barrières de l'octroi. Il est donc permis d'énoncer ceci : que *vivre c'est lutter*.

Let us say that every organism is under the obligation of upholding its bio-economic integrity, and that this implies maintenance of the symbiotic disposition, *i.e.*, obedience to the law of co-operation under penalty of disease and pain. If the means of defence are, normally, as high as they are here admitted to be, if they depend upon (phagocytic) Symbiosis, as here described, and if the defensive power of the epithelia is dependent upon proper nutrition, this renders it only the more evident that its inherent integrity is the true safeguard of the organism. The case, in other words, does not stand so chaotically as the constant reference to "lutter" would make it appear, and the "lutte" itself is largely a bio-moral "lutte." But he who says "lutter," generally wishes thereby to shelve the inconvenient questions as to sociology and the "inner nature of the organism." He wishes to divert the attention from these subjects, a proceeding which has the effect of converting the philosophy of life into necrology, and of conducing to moral and intellectual damage. No organism can live well without maintaining sufficient symbiotic integrity—this is the law of co-operation and the law of life. Although Dr. Larger wishes to introduce an alternative "lutte" to Darwin's "lutte pour la vie," he has yet overlooked the fundamental alternatives to "lutte," which are: work and co-operation.

Consider the following symptoms of degeneration as enumerated by Dr. Larger :

Chez le dégénéré, toutes les fonctions de nutrition et de relation s'altèrent. La respiration et la circulation sont défectueuses. Il en résulte une hématoze insuffisante, d'où : propension aux affections pulmonaires et vasculaires, à l'anémie et à l'artério-sclérose notamment. La digestion devient la *dyspepsie* ; la sensibilité, le *nervosisme*. Le système musculaire, mal nourri, mal innervé, s'atrophie. La fonction de génération surtout subit les atteintes, les plus graves. Chez l'homme, ce sont des troubles génitaux variés, le conduisant à l'impuissance et à la stérilité.

What does all this imply ? It implies a loss of "normals" —those of nutrition, of respiration and of circulation, and also those of generation, which "normals" we have seen, broadly speaking, to be the correlates of normal bio-economic behaviour.

Evidently a foremost place is occupied by metabolic abnormality, and we may feel certain that in Nature this is generally caused by predaceous feeding or by in-feeding with the implied transgression against the symbiotic order of nature and the consequent physiological sterility.

As against Dr. Larger's account of degeneration in man, we may here set an account of man's frequent unsymbiotic behaviour, as recently supplied to the *Lancet*, though with a totally different thesis than the one here propounded, by Dr. Harry Campbell, F.R.C.P., Alienist and Anthropologist. He tells us that

in the matter of slaughter he (man) leaves all other animals far behind. He is the arch-slaughterer—*facile princeps*. Since the time the pre-human ape took to hunting he and his human descendants have wrought ruthless havoc among the lower animals, and at the present day man not only hunts them, but breeds them for the express purpose of destroying them, chiefly for food, partly for amusement. Many a person of gentle nature would be amazed and horrified were he at the end of a long life to see *en masse*, the hecatombs of living things done to death on his behoof.

Such being (part of) man's biological behaviour, we cannot be astonished at the prevalence of disease and of degeneration.

On Dr. Larger's view, Tuberculosis is “ la maladie dégénérative par excellence.” This we are told in capital letters and with many examples from animal and human races. “ Elle s'attaque aux organismes usés, comme les Moisissures aux vieux troncs.”

It would, however, be more correct, I think, to regard the attack as of the same nature as that of the hyper-parasite upon the parasite, *i.e.*, largely as a form of biological retribution.

Curiously enough, Dr. Larger himself is tempted to speak of the parasitic micro-organism as of an “ executioner,” although, of course, he is far from avowing any kind of moral or bio-moral delinquency on the part of the “ executed.” Thus, in wishing it to be understood that it really does not matter what particular disease it is that is responsible for degeneration, he tells us that not only Tuberculosis, but other diseases, too, may play the rôle of the “ executioner.” He says :

cet office d'exécuteur peut être rempli par n'importe quelle maladie infectieuse qui trouve toujours dans la Dégénérescence son terrain d'élection.

At this point, however, feeling perhaps that the task of discovering the true cause of degeneration is beyond him, the author would fain discard any further quest of cause as “ un simple intérêt de curiosité.” Curiosity forsooth !

That "selection" very generally induces, not genuine improvement, but, on the contrary, disease and degeneration, is acknowledged by the author thus :

on crée forcément des adaptations nouvelles par les changements de milieu et de régime, de suralimentation, etc. On provoque intentionnellement des spécialisations unilatérales excessives : le développement exagéré du système musculaire, pour la production de la viande chez les *Bovidés*, pour favoriser la course chez les *Equidés*, etc. C'est ainsi qu'on a singulièrement multiplié la tuberculose des *Bovidés* "trop améliorés"—ce qui, en langage biologique, doit se traduire par "trop spécialisés." Et parfois des lauréats de concours agricoles ont été saisis à l'abattoir comme viande tuberculeuse. Le fait s'est produit, notamment, il y a une quinzaine d'années, pour le taureau, lauréat du grand prix du concours général de Paris.—Tant il est vrai que la Roche Tarpéienne est près du Capitole !

Jean Jacques Rousseau would have told us that we have here mainly an instance of bad biological behaviour on the part of man. His modern countryman, albeit with much greater erudition, or, perhaps, because of this, endeavours to explain the biology of the case by a vague and semi-sociological term, whilst at the same time implicitly denying the sociological factor. If we were at least told wherein normal "specialisation" consists ! The morale of the case seems to be mainly this, that "suralimentation" of one kind or another produces morbid growth and monstrosity, be it in Nature or in Domestication. If History was to be invoked at all, in interpretation of the "laureate's" fate, then it should have been shown that the monster's "misère," if not entirely self-caused, was yet typical of the retribution befalling those types which from whatever cause indulge in acromegalic habits and desires. We are further told :

Mais il arrive non moins souvent que, sans devenir tuberculeux, ces mêmes animaux, purement sélectionnés, dégénèrent néanmoins par suite du simple changement des conditions biologiques (nourriture trop substantielle, etc.), auxquelles on les soumet, et perdent plus ou moins leurs qualités reproductrices.

A fortiori should this observation have caused the author to pause and to consider the importance of feeding in degeneration. It might have struck him that the same cause which is so potent in the rapid degeneration of domesticated races, though Tuberculosis be absent, may be, in some way or another, the chief cause of the gradual degeneration of races in Nature. It might have struck him that there remained as yet some important laws of nutrition to be enunciated. Instead of which, all we get is the

cheap philosophy of "*tempus edax rerum.*" There is also this to be said : Dr. Larger has insisted on the normality of Parasites, in view chiefly of their apparent fecundity. Now, as is well known, the chief pre-requisite of Parasitism is an abundant nutrition. How comes it that animals in Domestication, with sluggishness of life and over-feeding as the norm, lose their reproductive qualities, whilst Parasites, still more sluggish, and still more indulgent in a "royal diet," *i.e.*, under much the same physiological conditions, yet fail to lose their reproductive capacities? The answer is that the physiological contradiction is not real but only apparent, that Parasites are in effect losing this capacity, and that it is only the blindness of Biologists which does not see that there is really failure of genuine fecundity. The compatibilities are merely different. The Parasite loses one part after another in compensation for indulgence, whilst the higher organism, liable to different compensations, can far less afford to do so and may have to pay the penalty for indulgence with his life. In either case, however, the analogous diathesis tends to produce an identical result, namely, a curtailment of the specific powers. If, according to Dr. Larger, Domestication frequently results in "*avortements spontanés,*" it may equally be said that the Parasite's losing game of life is equal to an "*avortement perpetuel*" of the species. Very aptly the author himself says on p. 109 :

L'individu primitivement normal, mais ensuite diminué dans sa vitalité par les causes ci-dessus énoncées, engendre des êtres dont la vitalité est elle-même affaiblie et cela, de plus en plus, *car l'observation démontre qu'un dégénéré produit généralement de plus dégénérés que lui. De telle sorte que la Dégénérescence devient progressive par l'hérédité.*

Let us say that the individual suffers a diminution in its vitality chiefly as a result of "suralimentation," and that, only too commonly, heredity is the worse for it. Whether, in the author's words, "*la gravité des tares dégénératives devient incompatible avec la vie,*" depends, as I have said, on the status and character of the particular species. In a micro-organism, the same diathesis as that in a higher organism is only too likely to produce different phenomena, though in either case the nett effect is that of a loss of vitality.

A dim recognition of what I have called "spiritual law in the natural world" may be said to occur on p. 119, where the author

adumbrates that there is a struggle between Good and Evil, *i.e.*, between physiological and pathological factors, a

lutte du Bien et du Mal—lutte incessante, avec des alternatives de succès et de revers de part et d'autre et cela, depuis l'état embryonnaire jusqu'à la mort de l'individu ; depuis l'apparition jusqu'à l'extinction du groupe ; mais lutte dans laquelle, nous venons de le voir, le Mal finit toujours fatalement, bien qu'à la longue, par l'emporter sur le Bien.

This amounts almost to a religion of fatalism, and it has its basis in the fact that the founder only begins with the symptoms of comparatively advanced disease, the phase past redemption, and ignores the inceptual stage, including the real "raison d'être" of the conflict concerned. The fatal ending of the Degenerate is not at all to be regarded as a victory of Evil over Good. What is past praying for is eliminated : that is all. The "Good," *i.e.*, the bio-economically useful, survives.

In arguing that it is "Dégénérescence," and not "Natural Selection," which is chiefly responsible for destruction, the author tells us that it is a great error to believe that the approaching extinction of elephants and whales is due to the action of man :

La vérité est que ces animaux sont en train de disparaître parce qu'étant considérablement réduits et amoindris par la Dégénérescence—démontrée par les lésions anatomo-pathologiques de l'*Acromégalie-Gigantisme*,—la destruction brutale [chasse] peut s'opérer et s'accomplir efficacement. Cette action serait au contraire négligeable, comme elle l'est chez les lapins et les Rongeurs en général, si les Eléphants et les Baleines étaient, de même que ces derniers, des animaux *normaux*, c'est-à-dire capables de réparer leurs pertes par une extrême fécondité : ce qui n'est pas.

We have seen, however, that "Dégénérescence" is no more the true cause of extinction, than extreme fecundity is a symptom of genuine survival. Man, by his inferior instincts, becomes a kind of scavenger, a kind of "executioner," to whom many over-fed and morbid types fall a prey much in the same way as they do to parasitic micro-organisms. We need not, therefore, deny the well-known agency of man in the destruction of these types in order to bolster up a distinctive "Contre-Evolution." What we need to do is this : to apportion the rôle played by the respective appetites in determining the fate of the organism. Dr. Larger's continuation, indeed, very pertinently provokes such an interpretation :

Pareil fait à celui qui s'est passé à la Jamaïque arriva en Australie où les conditions, en dépit de la grandeur de l'île, sont cependant

comparables, au point de vue de la Ségrégation géographique, car les déserts centraux de l'Australie tiennent lieu de barrières infranchissables. Il y a un certain nombre d'années, en effet, quelques couples de *lapins* y furent acclimatés. Mais il advint que les lapins se multiplièrent à ce point qu'ils devinrent un vrai fléau pour le pays. Tous les moyens de destruction outre la chasse [pièges, poisons, virus pathogènes, etc.] étant épuisés, on eut recours aux *chats* qu'on acheta en grandes quantités en Europe et en Amérique. Les chats, il est vrai, détruisirent les lapins. Mais les chats, à leur tour, dévorèrent les *oiseaux* et les *poules*. Ils finirent par s'attaquer aux *agneaux* et aux *moutons* eux-mêmes. Pour le coup, on songea aux *chiens*. Or ces derniers, devenus sauvages, dévorèrent tous les autres animaux, sauvages ou domestiques!

A round of events similar to this also applies in Nature, in the shape of “ checks,” spoken of in a previous chapter. The nett effect of such “ checks,” as I have stated, is to ensure the protection of the fundamental capitalist: the plant. Appetites, unrestrained by Symbiosis, lack the permanent element, *i.e.*, in their inordinate growth they become self-destructive, and eventually cease to be even indirectly useful. It is thus the uselessness of the whale and the elephant which is the final cause of their morbidity and disappearance. The elephant, being at least a cross-feeder, is easily the more useful and also the more sympathetic of the two, and its chances of life, therefore, are greater than those of the whale. Unwittingly Dr. Larger provides exceeding good testimony for my view respecting the superiority of cross-feeders. Thus, of the negroes in the United States, contrasting them with the Red Indians, he says:

Bien que placés dans des conditions identiques, ils prospèrent néanmoins et voient même leur population s'accroître dans des proportions telles que la *question Nègre* en est devenue un problème inquiétant pour l'avenir des Etats-Unis. Et cependant ils ont été soumis, encore un coup, aux mêmes épreuves que les Peaux-Rouges, ont subi les mêmes brutalités de leurs premiers maîtres, leurs mêmes contacts physiques et moraux, avec cette circonstance très aggravante, que, déracinés de leur pays d'origine, l'Afrique, ils ont dû s'adapter à un nouveau climat et à de nouveaux milieux. Il y a là une contradiction apparente, mais qui s'explique très bien. Les Nègres africains, en effet, *race inférieure*, sont doués d'une vitalité extraordinaire, dont ils nous offrent le spectacle dans leur pays d'origine où ils résistent si étonnamment à toutes les causes de destruction telles que: guerres, esclavage, disettes, maladies. *C'est ainsi, par exemple, qu'ils jouissent d'une immunité à peu près complète pour la fièvre jaune, et, relative, pour la malaria.*

A ce propos, Boudin (Soc. Anthropol., loc. cit., 1860): “Cite l'exemple d'une expédition anglaise où les Nègres jouirent d'une immunité remarquable pour le paludisme auquel succombèrent beaucoup d'Anglais.” Chez

eux, comme chez tous les races non dégénérées, *les plaies ne suppurent que peu ou point*, tant est énergique leur phagocytose, ainsi que je l'ai déjà fait remarquer (Congrès français de chirurgie, 1899). Par contre, chez les dégénérés, le pus se forme avec facilité et abondance et leur phagocytose est très affaiblie. On peut dire dès lors que *la faculté d'adaptation des Nègres est maxima* et l'on comprend très bien qu'elle leur ait permis de résister à toutes les conditions défectueuses nouvelles résultant de leur transplantation d'Afrique en Amérique.

But whence the extraordinary vitality of the negroes? Are they a "race non dégénérée" for no other reason than that they are a "race inférieure"? Surely this is not a very plausible explanation, nor one worthy of a Physiologist or of a medical man! But the physiological cause of this vitality and the true explanation of the contrast between Red Indians and negroes, which Dr. Larger has entirely overlooked, I submit, are these: the Red Indians are mostly in-feeders, hunters, warriors and meat-eaters; whilst the negroes, especially in their "pays d'origine," are chiefly cross-feeders. In his work on Leprosy, the late Sir Jonathan Hutchinson reports that the Zulus, the physically finest race of African natives, live upon maize, millet and the productions of their herds. They have a strong prejudice against fish as food, and, as a rule, never eat it. Sir Jonathan was told that no girl would marry a man who admitted that he had been in the habit of eating fish.

If Dr. Larger, as he says, has demonstrated, that the immunity to disease on the part of the negroes depends upon their great power of Phagocytosis, then he has in reality proved that this power of resistance, this ability to depend upon biological support, consists in Symbiosis, as previously defined by me. Phagocytosis is but another word for internal or domestic Symbiosis, which, as the example shows, largely depends upon appropriate feeding habits, *i.e.*, above all, on cross-feeding. It is chiefly amongst cross-feeders, again, that we find those remarkable powers of adaptation dwelt upon by the author. Even in captivity this is very noticeable. Thus, according to R. Lydekker, whilst the little insectivorous bats, the flying-foxes of Australia (*Pteropus poliocephalus*), like our own species, give some trouble to keep, the big tropical fruit-bats are very easy subjects, and, in the London Zoo, the African collared species (*Cynonycteris collaris*) bred generation after generation in some cages in the Monkey House years ago.

We may say, therefore, that the physiological superiority of

the negroes is due to a high degree of biological integrity, notwithstanding inferiority in other directions. Physiologically, they do not deserve to be classed as an inferior race, and one would rather exclaim with regard to the cause of their immunity to microbic attacks : " vraie noblesse nul ne blesse." Absence of biological integrity and absence of Phagocytosis go together. Thus, as previously noted, in the notoriously parasitic Nematodes, no wandering phagocytes have been discovered, and the same is true of other lowly types.

When Dr. Larger surmises with regard to the Red Indians that " leur race était sans doute, dégénérée quelque peu, avant la conquête de l'Amérique, comme l'était certainement celle des Astèques," this is merely " répondre en Normand." We want to know the reason, the physiological reason, for this early phase of degeneration. " Over-specialisation " and " Over-Evolution," or " Contre-Evolution," are mere words explaining nothing.

It is well known that the class *Cephalopoda*, comprising the Cuttle fishes, Squids, Pearly Nautilus, etc., are all marine and carnivorous, and it is interesting to learn from Dr. Larger that the study of their past orders has helped to engender some sympathy amongst Palæontologists with the idea of

Dégénérescence-Maladie : C'est ce qu'exprime clairement un jeune savant français prématurément disparu, Félix Bernard : En général, dit-il, les formes ainsi modifiées sont frappées d'une sorte de *débilité congénitale* qui les rend moins aptes à la lutte pour la vie et ne donnent pas une longue série de descendants : c'est ce qui arrive pour les *Céphalopodes déroulés* qui atteignent une assez grande taille et disparaissent ensuite brusquement ; ce fait se produit à diverses époques et aux dépens de groupes distincts. Il est accentué surtout pendant la période Crétacée. Il semble, à la fin de cette époque, que le groupe entier soit malade.

Bernard's intuition, respecting the morbidity of monstrous size, however, was confined to the Cephalopods, according to Dr. Larger, who here again raises the absurd claim that no one but himself had ever thought of connecting extinction with pathology. Thanks to the law of " Atténuation," so Dr. Larger thinks, a giant animal race, though morbid, may yet remain able to procreate for considerable periods of time. An acromegalic giant, such as an elephant, according to him, suffers merely from monstrosity. It is more or less " en état d'imminence morbide." It is in a state of grave degeneracy,

Mais non pas au propre, un malade. C'est ce qui explique comment

il se fait que l'animal acroméganique-géant soit encore capable, quoique faiblement, de procréer [exemples : Eléphants, Baleines, etc.].

This, it seems to me, is putting too fine a point upon the distinction between morbidity and disease. Procreation *per se*, to my mind, proves little ; it may proceed for a long time though attended by disease. The good physician is he who recognises such disease though masked by the remaining components of health.

We learn that the comparatively slight cases of human acromegaly are much more common than is usually thought, and it has been found that "les variations extrêmes de la taille relèvent toujours de causes pathologiques," with which I fully agree.

For a more exact account of the various "stigmates tératologiques, psychiques, névro-pathiques ; asymétries ; dénivelllements de la taille des familles ; dystrophies gigantiques ; dysharmonies de diverses parties du corps ; développements précoces," marking the degenerate types, I must refer the reader to the book itself. We are told that "chez les Vertébrés géants les plus supérieurs, tant actuels que fossiles, on ne constate que rarement l'absence des lésions anatomo-pathologiques de la Dystrophie acroméganique."

The exception, apparently, is formed by some cross-feeding mammals, such as "*Cervus Megaceros* (fossile) et *Cervus Wapiti* (actuellement en voie de disparition au Canada), chez lesquels cette absence de lésions acroméganiques paraisse plus ou moins établie."

Evidently cross-feeding is answerable for many circumstances favourable to prolonged viability of the species.

Man, according to the author, is affected by comparatively simple forms of Gigantism, whilst

les formes du Gigantisme acroméganique et de l'Acromégalie simple, ou accompagnée de Nanisme, sont au contraire des types de dysostoses appartenant pour ainsi dire exclusivement à la *Dégénérescence animale actuelle et fossile*.

Dr. Larger is of opinion that the reason for the disparity between human and animal gigantism must be sought in the comparatively enormous cerebral differentiation of man. I would rather say that the disparity has its source in the fact that man's ancestors were symbiotic cross-feeders, far excelling in biological integrity all other types, and, further that the graver forms of

Acromegaly are incompatible with man's evolutionary status, similar to the way in which, on the physiological side, regeneration of limbs is incompatible with the status of the higher animal.

The following is Dr. Larger's formula respecting the zoological distribution of "Gigantisme":

le Gigantisme simple est celui des Dégénérés supérieurs et le Gigantisme acroméganique, celui des Dégénérés inférieurs—en donnant même à cette dernière appellation le sens de bestialité.

The contrast, therefore, is between bestiality, with its extreme degeneration, and the sympathetic, *i.e.*, symbiotic, organism which, by its very nature, by its superior character, is debarred from descending to the lowest depths of degeneration.

The whole skeleton, according to Dr. Larger, is eventually affected by Acromegaly; and he mentions the following important symptoms: "dilatation des Sinus cranio-fasciaux; l'ostéoporose ou l'ostéosclérose de tous les os; la dilatation des trous osseux vasculaires et nerveux; les saillies des insertions musculaires."

There are two types of Acromegaly so far as the structure of the skeleton is concerned: "le type long et mince et le type large et épais (Macroplastie et Euryplastie)," both occurring occasionally in man, although it is the "euryplastic" type that is the commoner of the two:

Mais d'une manière générale, tant chez l'homme que surtout chez les animaux (*Prohoscidiens, Grands Cétacés, Siréniens, Megatherium, Dinosauriens*), c'est le type d'Acromégalie dit épais et large ou *euryplastique* qui l'emporte. L'on peut dire que ce qui s'observe le plus souvent chez l'homme, principalement, *c'est le mélange en proportions variables, des deux types*; non seulement sur le même individu, mais encore, sur le même crâne. C'est ce que démontrent les autopsies relatées par Launois et Roy et d'autres encore. *L'irrégularité d'épaisseur des parois du crâne humain*, notamment, a même été donnée par Bécclère comme étant un caractère de l'Acromégalie humaine, bien que cette irrégularité soit bien loin d'y être constante.

We may well believe that frequently enough the thickening of the walls, incidental upon general mal-nutrition, is but a forerunner of their extreme porosity. The phenomenon is symptomatic of the way in which every undue exuberance of life is followed by general exhaustion.

We learn that amongst the races of man a well defined acromegalic type was confined to the Neanderthals. Modern acromegalic human giants are all completely sterile, which precludes extremely pathological characters from becoming fixed

by heredity as they otherwise would, and as they actually do in the case of animals.

It is interesting in this connection to note that the author distinguishes between "stérilité immédiate," *i.e.*, "l'inaptitude absolue à féconder ou à concevoir ; and "stérilité médiate," *i.e.*, "l'infécondité relative, c'est-à-dire, celle où la natalité n'est que notablement affaiblie, dans le principe ; mais devient par la suite, complète."

There is thus, no doubt, a gradual exhaustion of the procreating power, *pari passu*, I believe, with the gradual intensification of the parasitic diathesis. What Dr. Larger omits to state is this, that in the majority of cases the precursor of this gradual exhaustion was a more or less intensified redundancy, an undue exuberance of life, which, though originally deriving its power from Symbiosis, yet very commonly transgresses the bounds of symbiotic restraint, which led to reactions of an injurious order.

According to the author, there is a fair consensus of opinion among *savants* that the cause of the acromegalic affection of the skeleton is ultimately to be found in "un trouble de nutrition osseuse." Hence Dr. Larger's term "dysostose acromégalique," which he conceives to be a part of the general "dystrophie acromégalique" of the entire body—"squelette et organs splanchniques."

Beyond such surmises, however, we get no approach to the elucidation of the real problem, namely, as regards the nature and significance of the nutritive failure. Dr. Larger's strength evidently lies in classification rather than in explanation. He is, of course, chiefly concerned with specification, with the task of outlining palæo-pathological stigmata. To this end he first wishes to establish a "signe pathognomonique invariable de la Dysostose acromégalique," and as such he recognises above all what he terms "la Sinusomégalie"—

La dilatation ou le Rétrécissement des sinus cranio-faciaux,—spécialement, de ceux du Frontal—par l'effet de la Dysostose acromégalique invariablement concomitante de leurs parois ; soit par Ostéoporose ou Ostéosclérose, soit, le plus souvent, par l'association des deux.

We learn that

la Sinusomégalie surtout frontale, est le signe pathognomonique de la Dysostose acromégalique, tant chez l'homme que chez les Mammifères actuels et fossiles doués d'un cerveau centralisé, . . . la Sinusomégalie, soit cranienne, soit vertébrale, n'étant au fond qu' une ostéoporose

d'outrance, constitue en général, chez les Vertébrés, le caractère à la fois le plus décisif et le plus constant qui se puisse voir de la Dysostose acromégalique.

It would be impossible here to enumerate all the various “signes pathognomoniques adjuvants ou secondaires,” as laid down by the author. Suffice it to emphasise the fact, to which he himself witnesses, namely, that mal-nutrition of one kind or another is entailed in the respective pathology.

An interesting point occurs with regard to the explanation of the ossification of the ligaments and of the intervertebral muscles in the case of some *Dinosauria*. This is what we are told :

Or les ossifications ligamenteuses et musculaires se montrent exclusivement chez les Iguanodons, alors que tous les Crocodiliens en sont exempts !

Comment expliquer cela ? se demande l'éminent professeur de Bruxelles (Dollo) pour qui d'ailleurs l'Acromégalie est chose absolument inconnue ! Il ne pense naturellement qu'à une explication par la Physiologie normale, explication qu'il emprunte à Barkow. Nous ne le suivrons évidemment pas sur ce terrain, qui n'est pas le vrai, nous bornant à relater ici sa description inconsciente de la Dysostose : “Ce sont, dit-il, des sortes de cordelettes osseuses [car les ligaments et muscles sont *ossifiés* et non pas *pétrifiés* : l'auteur établit lui-même la distinction ce qui est très important) embrassant, à droite et à gauche, la colonne vertébrale, dorsalement aux diapophyses et commençant généralement à la fin de la Région cervicale, pour se continuer, sans interruption, dans les régions dorso-lombaire et caudale, ne s'arrêtant que quand les lames des neurapophyses cessent d'exister, etc. Ils rentrent donc dans la catégorie [catégorie incontestablement *pathologique*] des ligaments dérivés de muscles entiers par suppression des fibres musculaires et ossification subséquente : Muscles sacro-lumbalis, spinalis dorsi, multifides spinæ, obliquo spinalis.” Et l'auteur—lequel, aux yeux de quiconque a l'honneur de le connaître, ne méritera jamais le reproche de prolixité!—termine son très bref, mais fort substantiel et très intéressant Mémoire, par cette remarque que nous enregistrons non sans satisfaction, à savoir : “qu'il existe la plus grande analogie entre la disposition des ligaments ossifiés des Iguanodons et celle décrite par Owen chez *Apteryx*.” Et il ajoute ceci : “Les Ratites sont de tous les Oiseaux, ceux qui présentent le plus d'affinité avec les Dinosauriens.” L'excellent professeur Dollo *n'oublie qu'une seule chose, c'est de nous dire le point commun aux Ratites et aux Dinosauriens, à savoir : l'Acromégalie.*

We may fitly compare the loss or ossification of muscular fibre in the case of the Dinosaurs, to the loss of regular fibre in the case of plants which have ceased to draw on soil and atmosphere having yielded instead to parasitic propensities. And we may interpret the convergence between *Dinosauria* and *Ratitæ*, noted by Prof. Dollo, as one due to a parallel retrogression from a

previous normal and symbiotic to an abnormal and comparatively parasitic habit of life.

A somewhat similar convergence, only on a smaller scale, was noted by Darwin in the case of domesticated pigs. To some extent Darwin seems to have realised that the phenomenon is due to a pathological cause. For in his *Variation of Animals and Plants*, Vol. I., p. 90, he states that the phenomenon is due "to similar causes of change acting on the several races, and partly to man breeding the pig for one sole purpose, namely, for the greatest amount of flesh and fat" (*i.e.*, man is over-feeding and at the same time under-exercising the creature, which is certain in the long run to induce morbidity).

On the other hand, Darwin, always open to the possibilities of re-conversion, notes in the same volume (p. 95), that pigs and other animals, when allowed to become feral, tend to lose their monstrosity and to revert in the general shape of their bodies—"as might be expected from the amount of exercise which they are compelled to take in search of food."

In the case of cattle, he says that "we cannot doubt that an active life, leading to the free use of the limbs and lungs, affects the shape and proportion of the whole body," whence it should not prove too great a step to the recognition that a definite ratio of food to work, such in fact as provided by the contingencies of Symbiosis, is indispensable to normal "specialisation."

In view of the great physiological importance of this ratio, I would introduce the expression f/w ($\frac{\text{food}}{\text{work}}$) as a way of representing a norm of behaviour upon which almost everything in Biology depends.

It is also significant that Darwin compares the case of monstrosity amongst cattle, *e.g.*, the niatas, to that of the over-fed pig or bulldog. Nay, he goes further, and, taking care to indicate several interesting pathological stigmata, he makes a comparison with the case of the gigantic extinct *Sivatherium* of India, showing that in either case we have the lower jaw projecting beyond the upper, with a corresponding upward curvature, etc., etc.

Seeing that I cannot emphasise too much the parallelism between the pathology due to sluggishness, over-feeding, and Parasitism in Nature, and the one induced by a perverted f/w ratio in Domestication, a further digression respecting Darwin's views on these matters may not be out of place. "It

is almost certain,” he says (*loc. cit.*, p. 112) “that abundant food given during many generations directly affects the size of a breed.”

Surely the same is true in the case of abundant food “taken” by a species in Nature, more especially so if there is a lack of habitual counter-services. Had “selection” not been so dear to Darwin’s heart, had he fully appreciated the importance of the f/w ratio, he would, no doubt, have come to realise that artificial selection is too closely associated with Pathogenesis to exemplify the process of normal evolution.

He would have realised the extreme physiological importance of the bio-economic nexus existing between organisms, be it on the small or on the large scale of Nature. Darwin was evidently greatly struck by the bad effects, extending even to the anatomy of the creature, of surfeit, confinement, and one-sided exploitation of organism by organism, as evinced by the case of Domestication. Thus he notes the elongation of the skull relatively to its breadth, and the antithesis between size of brain and of body—developments obviously analogous to those seen in the monstrous types in Nature. He states (p. 143) :

The explanation seems to lie in the circumstance that during a number of generations the artificial races have been closely confined, and have had little occasion to exert either their senses, or intellect, or voluntary muscles ; consequently the brain, as we shall presently more fully see, has not increased, the bony case enclosing it has not increased, and this has evidently affected through correlation the breadth of the entire skull from end to end,

And again (p. 157) :

We thus see that the most important and complicated organ in the whole organisation is subject to the law of decrease in size from disuse.

To “disuse” we must now, however, add “misuse.” With this addendum it is fairly obvious that there is a unity of disease, be it in the case of monstrosity in Nature, or in Domestication, as exemplified by Darwin’s findings. In either case we have a perverted f/w ratio, with the implied divorce from Symbiosis. If he does not provide instances of ossification, Darwin at any rate shows that by way of correlation every suture in the skull as well as the form of the lower jaw (asymmetry of the condyles) is often greatly affected in Domestication. “How erroneous,” he exclaims, “to say that only parts of slight importance become modified under domestication.” Yes, but above all it is necessary to recognise that for the most part

these modifications appertain to the pathological order and are the opposites of those produced in normal evolution. The modifications under Domestication redound little to the credit of "Selection." Justification for this view is again afforded by Darwin's own subsequent remark respecting the domestic rabbits, concerning which he tells us (p. 157): "By the supply of abundant and nutritious food, together with little exercise, and by the continued selection of the heaviest individuals, the weight of the larger breeds has been more than doubled." Obviously Darwin felt constrained, by the force of the evidence, to give pride of place to two positive factors, namely (a) food, and (b) exercise, whilst the negative factor: destruction (selection) takes third place, as certainly it should.

Supposing, in the place of Darwin's phrasing, we put the case thus: By the *continued* supply of abundant and highly nutritious but *unnatural* food, together with too little exercise, the size of the organism becomes pathologically increased. By making exploitative use of the principle of compensation, man induces a hypertrophy in some parts together with an atrophy in others. By the destruction of those animals which lend themselves least to man's exploitative purposes, the abnormality of the survivors (the "selected") tends even to be increased. The whole process, except for some mitigating circumstances, is one of systematic, non-symbiotic and semi-parasitic exploitation, which cannot but be physiologically injurious, *i.e.*, it is pathological in effects. The term "Selection," therefore, fails to convey what is chiefly entailed in Domestication. "Darwin," says De Vries, "was never quite clear about the physiological part of the theory of Selection."

But who amongst recent writers sees clear in these matters? Who has shown that physiology is above all determined by biological behaviour?

But to return now to "Contre-Evolution." It is when we come to Dr. Larger's treatment of the ætiology of "Gigantisme acromégalique" that we are afforded the utmost justification for concluding that surfeit and in-feeding are largely responsible for the implied Pathogenesis. Frequently the abnormalities, atrophies, precocities and disharmonies are quite obviously of the same character as those occurring in Domestication, or, still more so, in rank Parasitism. There is, first of all, the case of some giant tadpoles, discussed at considerable length by Dr. Larger

and diagnosed by him as Acromegaly. What is omitted, and what has to be borne in mind above all, is this, that although tadpoles are mostly cross-feeders—pointing to a one-time purely cross-feeding ancestry—yet the adult frogs are frequently inveterate in-feeders, taking large toll of insect and other life, which must give rise to a diathesis and likewise to infection. All carnivorous or insectivorous animals suffer from food-borne infection, and anyone dissecting a frog can, as a rule, detect some parasite. Acromegaly here, according to Dr. Larger, is due not to a local but to a general cause :

une cause de nature toxi-infectieuse—ce qui est prouvé par l'invasion uniforme de tous les tissus par les leucocytes et les cellules éosinophyles, cause efficiente des processus à la fois hyperplasiques et atrophiques dont ces mêmes tissus sont le siège.

But, surely, the chief cause behind Dr. Larger's "non-local" cause, is in-feeding, the bad effects of which universally lead to antitheses as here portrayed. In this connection the author again insists that there is a pathological reason for the fact that we never meet with "Gigantisme acroméganique" at the beginning of a phylum, without, however, being able to specify the true reason for the comparatively late incidence of the visitation. All he can tell us is that some ancestor must have left a "hérédité pathologique." The phenomenon, however, can be accounted for by the view that the beginning of a phylum is everywhere made by cross-feeding and by such wholesome biological activities as preclude disease. Such behaviour alone leads up to a fruitful patrimony. The frailty of life, however, is such, that wholesome development is frequently followed by abuse, leading to the growth of a parasitic diathesis, which finally leaves the organism, if monstrous, yet bare of viability and of power of orientation in the world of life. Though without any subjection to the will of man, or, for that matter, to that of any other creature, the acromegalic organism ultimately loses the ability of duly fending for itself and of adapting itself progressively. Its life and constitution are no longer congruous with the leading socio-physiological contingencies of existence. Its very existence is an anachronism in modern evolution.

Acromegaly, human or animal, is marked by "anarchie glandulaire"—in the absence, I should say, of a perfect glandular balance. And this balance depends upon (a) internal symbiosis, and, concomitantly, (b) upon external Symbiosis, the

two mutually complementing each other ; for, be it with glands, or organs, or organisms : all have to comply, jointly as well as severally, biologically as well as physiologically, with the all-embracing socio-physiological law of progress, the law of Symbiogenesis.

The following are some acromegalic stigmata applying to man and beast as observed by an autopsy and cited on p. 283 of Dr. Larger's work :

On trouve, outre les dysostoses que nous avons décrites précédemment : " une tumeur du corps pituitaire grosse comme une mandarine. Le foie, la rate et les reins hypertrophiés. L'utérus tout petit, portait 2 ovaires atrophiés.—Pareille atrophie complète des organes génitaux mâles se voit ailleurs. Les capsules surrénales sont volumineuses. Enfin et surtout, le corps thyroïde est énormément hypertrophié, avec 4 parathyroïdes considérablement augmentées de volume.—En résumé : tous les organes splanchniques sont plus ou moins intéressés ; les uns, hypertrophiés, les autres, atrophiés—*l'hypophyse y comprise, peut-on dire !*

It is therefore certain, says the author, that " l'origine et la nature toxi-infectieuses générales sont démontrées à la fois par la Pathologie humaine et par la Pathologie comparée."

The Neanderthalian, as already pointed out, in the author's opinion, is the only human group " nettement dégénéré d'après le mode animal." This race was not

acromégalique individuellement et à titre exceptionnel, comme peut l'être l'homme actuel ; mais bien en tant que groupe entier, c'est-à-dire, de la façon dont sont atteints et disparaissent ou ont disparu la plupart des groupes animaux actuels et fossiles.

As to the lesions found, there have been shown to be various forms of Arthritis, often of a tubercular character. There are indications of Osteo-arthritis and of " polyarthrite alvéolodentaire." More precisely, Dr. Larger thinks the lesions due to " Rhumatisme tuberculeux," which disease is notorious for its osseous lesions—lesions to be found in the Neanderthalian skeleton and likewise in that of *Ursus spelaeus*.

No doubt, in-feeding and sluggish conditions, the analogues of those prevailing in Domestication, must be held responsible for the result. Dr. Larger says that especially during the late glacial periods, when man and animal lived under deplorable hygienic conditions, either in caverns or with insufficient shelter, and often without air and light and with insufficient food, tuberculosis was certain to have been rampant. And tuberculosis, " c'est la maladie dégénérative par excellence."

There is no doubt, I should add, that depredation and carnivorism were widely prevalent during those remote uncongenial ages, with conditions generally adverse to Symbiosis. Of *Homo Neanderthalis*, Dr. Larger further says that he constitutes

un groupe essentiellement dégénératif, formé exclusivement par un ensemble d'individus portant tous, sans exception, les caractères de l'Acromégalie. Ce groupe dégénératif est tout à fait comparable à celui des *Cétacés*, des *Dinosauriens*, des *Ptérosauriens* et des *Ratites* que nous avons déjà vus et à celui des *Proboscidiens*. Le groupe de “ l'Homo Neanderthalis ” est un groupe dégénératif bien plus homogène encore que ne l'est, à ce point de vue pathologique, celui des Anthropoïdes lui-même. . . De telle sorte qu'il est plus exact de dire, qu'au point de vue de la Dégénérescence en général, et à celui de l'Acromégalie, en particulier, c'est le Néanderthalien et non l'Anthropoïde, qui marque véritablement la transition de l'homme actuel aux groupes animaux dégénérés totalement : les Proboscidiens, par exemple.

It is only too likely, I should say, that the Neanderthalian race had attained to almost complete in-feeding—as corruption is often the greater the higher you go—which the Anthropoids had avoided, the latter thus escaping the extreme pathology of the former. Special circumstances, of course, may have contributed to this end. It is, however, interesting in this connection to find that another French writer, Gaudry, points to nutritional conditions as possible determinative factors. As Dr. Larger tells us :

Qu'il me soit permis à propos de cette même loi du Gigantisme, de réparer une omission tout à fait involontaire de ma part, relative à Albert Gaudry lequel a nettement entrevu la loi d'Augmentation ou d'Accroissement de taille, plus tard établie par Charles Depéret. Voici, en effet, ce qu'on lit dans un travail de Gaudry [ce travail est intitulé : *Essai de Paléontologie philosophique*, Paris, Masson, 1896, p. 67] : Il est vraisemblable que l'accroissement des Herbivores, qui forment les espèces les plus nombreuses, a été favorisé par l'extension des angiospermes et notamment les graminées ; l'accroissement des Carnivores a été à son tour favorisé par la multiplication des Herbivores dont ils faisaient leur nourriture. Mais certainement à ces causes, il faut en ajouter d'autres qui sont encore ignorées. Nous sommes arrivés à cet état de la Science où nous constatons beaucoup de choses, où nous en expliquons très peu.

Dr. Larger comments thus :

Gaudry, pas plus que Depéret, n'a vu la vraie cause de l'Extinction des Espèces par le Gigantisme. Pas plus que lui, il n'a eu l'intention de la Dégénérescence ; comme lui aussi, il soupçonne des causes qu'il ignore, et se renferme dans des réserves dénotant un esprit scientifique aussi réel que rigoureux.

But Gaudry has nevertheless adumbrated the direction in which we must look for the solution of the problem. The development of monstrosity amongst the Carnivora has been connected by more than one writer with the abnormal growth of their prey, as, no doubt, to some extent it was. Similarly, the monstrosity of the Herbivora was no doubt connected with the fact that their food-plants had increased in size and abundance. In either case there resulted a perverted *f/w* ratio. The expansion of the lower Angiosperms, in particular the Graminaceæ, may well have been a determinative factor of monstrosity. We have seen that there exists, for instance, an "alliance" between the grass and the grazing animal, which often enough may be regarded as an "unholy alliance," for it depends upon the destruction by the Herbivora of shrubs and trees, which would otherwise have been capable of offering them a superior class of food. The aforesaid "unholy alliance" means this: the fewer trees, the fewer fruits, although the more grass—an article, which, of course, is as easy of access as it is easy of expansion. The very presence of grass would seem to impair the fertility of fruit-trees. But this very ease of getting grass entails degeneration. It means a low instead of a high order of Symbiosis, and a corresponding physiological deterioration. The seed and fruit-eating animal is less liable to sluggishness and monstrosity than the herbivore, depending mainly upon grass, of which it consumes vast quantities in order to obtain a sufficiency of proteid and vitamine supplies. It is well known, moreover, that even the best cereal food, in spite of its tremendous importance, cannot vie in dietic value with nuts and fruits. As regards the facts of Natural History, so far as they are at present ascertainable, Dr. Edmund Sinnott, of the Connecticut Agricultural College, informs us that a radical change took place in the growth habits of many plants from a woody to a herbaceous type for the most part since the beginning of Tertiary time, and he thinks that this may well have contributed to the rapid evolution of Mammals subsequently occurring. Evidently we are here dealing with an undue exuberance of life, namely one that went on at the expense of symbiotic restraint, and, *pro tanto* was attended by pathological concomitants. We may say that an overflow of nutrition led to an overflow of evolution into pathological channels, the process being further aided by the implied retrogression in Symbiosis. It was a case of quantity *versus* quality, with corresponding

reactions in physiology and anatomy. Dr. Sinnott apparently has not realised that the exuberance of mammalian life, following upon the comparative dominance of the lowly herbs, was apt to be pregnant with the germs of decay, simply because it was based upon an " unholy alliance," and, as such, sociologically inferior.

If we carry our research further back in time, we find that the Pliocene age was the era immediately preceding the Glacial period. It merged itself into the Pleistocene, the period of *Pithecanthropus erectus*. According to Prof. E. W. Berry, another American writer, the Pliocene age probably witnessed the most profuse and diversified mammalian life and *arborescent* flora that the world has ever seen. It is highly significant that the fauna co-existing with the arborescent flora of that happy time was known as the " Hipparion " fauna, from the abundance at that time of the *small* fleet horses of the Hipparion type. Evidently the earth at that time was a *magna parens frugum*—and, concurrently, a great parent of normal, *i.e.*, non-monstrous animals—a time of " holy," *i.e.*, symbiotic alliances, with the restraining and balancing effects of Symbiosis clearly marked upon the structure of the animal.

When the Pliocene made way for the Pleistocene Glacial period, many of the early representatives of the human race evolved into nomadic hunters. Many of their descendants, having migrated westward in successive waves from the arid Orient, may have seen, as Prof. Berry says, the great glaciers of the Rhone and the Rhine ; they may have hunted the wild horses and mastodons in Southern France. More important from our point of view than the geological is the physiological sequence. For, inasmuch as these races became in-feeders, they degenerated until some of them, *e.g.*, the Neanderthals, reached the stage of the savage beast, marked by chronic Acromegaly—a degeneracy in which they exceeded the more conservative Anthropoids. Gaudry's palæo-physiological speculations, therefore, are not without foundation, although it remained to be seen how well they were founded.

Reverting now to Dr. Larger's book, it is interesting to find that the *Proboscidea*—typical Acromegalics, according to him—are characterised by nasal bones of small dimensions, a character which, as we are told, they have in common with present-day acromegalic man. All of which recalls the morbid shortening

of the head noted by Darwin in *Variation*, as the result of long-continued over-feeding in the case of the pig, bulldog, etc.—abundant and rich food supplied during generations tending to make the head broader and shorter (p. 89).

We may say that the phenomena are connected with indiscriminate feeding of one kind or another. Such feeding produces antitheses until, by way of compensations and of correlations, atrophies in certain bone structures arise simultaneously with morbid increases, or hypertrophies in others. Since the development of the senses depends upon exercise, and since the finer usage of the organ of smell is surrendered with a transition from symbiotic cross-feeding to indiscriminate non-symbiotic feeding, it is only too likely that a resulting diminution in the power of the olfactory organ leads to some under-nourishment of the organ and eventually to an atrophy in the nasal bones.

Dr. Larger has no difficulty in refuting the view expressed by many "Biologistes-normaux" to the effect that hypertrophied parts are merely a normal defence of the organism. Of course if it comes to a combat, he says :

N'importe quel animal, il fait flèche de tout bois, comme on dit : il se bat *unguibus et rostro*. . . C'est assurément cette impuissance complète à leur attribuer un rôle quelconque qui a déterminé les zoologistes—auxquels répugne l'idée même d'un organe inutile, et qui ne veulent pas admettre qu'un animal, normal à leurs yeux, puisse être tératologique en quoi que ce soit.—C'est, dis-je, évidemment cette idée fausse qui les a déterminés à se rejeter sur celle d'une arme de combat.

The inadequacy of the Darwinian concept of "utility"—lacking as it does, due standardisation—is thus again brought home to us. Usefulness *quoad* mere expediency is not the same as usefulness *quoad* advancement of life generally.

In speaking of the astounding development of the incisors in the *Proboscidea*, Dr. Larger further says :

Sans doute, que dans le principe, le rôle de ces *dents* devait être nécessairement fonctionnel, et ce n'est que dans la suite, que ce même rôle, cette fonctionnel a dû se perdre, par une cause pathologique. Aussi bien, cette dégradation insensible des "Défenses" découle-t-elle de l'histoire même du Rameau des Proboscidiens. Nous assistons ainsi aux phases successives de la Contre-évolution la plus intéressante, *Contre-Evolution s'exerçant sur un organe spécial tel que la dent*.

Il est incontestable, en effet, que chez *Moeritherium Lyonsi* (Éocène moyen et supérieur) les deux incisives externes du haut et du bas (qui deviendront plus tard les défenses) se touchant par leurs pointes, étaient

manifestement des dents utiles. Comme le dit Abel, “ son alimentation a dû être la même que celle de l'Hippopotame, à comparer les deux dentures.

And what about the “ alimentation ” of these animals ? I am inclined to attribute to it the chief importance in the production of the dental abnormality. The author's own remarks bear out my contention that the pathology of the case is intimately connected with its Bio-Economics :

La grande incisive inférieure servait à *déterrer et à ébranler les plantes* principalement aquatiques et paludéennes. (Italics mine.)

In other words, the animal had in course of time become a terrible plant-carnivore. What Dr. Larger overlooks is this : that the pathology really began precisely at the moment when the elephant, though still a cross-feeder, yet commenced to destroy wholesale higher plants—the chosen partners of the higher mammals—appropriating huge quantities of food without any biological counter-service. (Indian elephants devour the leaves of palm, fig and jak trees. In captivity a large “ tusker ” needs 800 lbs. of green fodder in eighteen hours.)

All that the author concludes is that the tusks have become what they are as a result of a pathological cause. What that cause is he cannot tell us, except by stating that evidently “ Contre-Evolution ” has exercised itself upon a special organ.

Far, far away, in the Eocene, the incisors had a more normal appearance, since they functioned more normally. That is to say, the animal was less predaceous, and, no doubt, filled some useful, *i.e.*, symbiotic rôle in the economy of Nature. Like all origins of elementary species, that of the elephant's progenitor was due to symbiotic cross-feeding. This engendered power, which the animal subsequently abused, if only by blind or unredemptive destruction of important vegetation.

We learn further :

Chez *Palæomastodon Beadnelli* (Éocène supérieur), les deux incisives médianes disparaissent, tandis que les deux externes d'en haut s'allongent et commencent déjà à dévier l'une de l'autre. Quant aux deux incisives inférieures, elles s'accouplent parallèlement en forme d'un véritable *double soc de scarificateur*—instrument, comme l'on sait, employé en agriculture,—elles sont évidemment destinées à fouiller le sol pour en dégager les plantes dont se nourrit l'animal : les incisives supérieures remplissant les fonctions d'un *contre double*. Les incisives inférieures, dit encore Abel, servaient à déterrer les racines et les bulbes, comme chez les Suidés actuels.

Here then we find a kind of agricultural implement employed

by an animal—not, however, on the principle of the true agriculturist, but rather on that of the ruthless robber. All animals, of course, may be said to make encroachments upon plant life, but it is plain that there must be well-defined limits, and, undoubtedly, in Evolution it is the little more or the little less that counts, particularly in matters of this kind. Given a pronounced predatory habit, it cannot be wondered at that the species became affected by a steadily increasing degree of Acromegaly until finally the whole otherwise long-lived genus became affected by a fatal pitch of “Gigantisme.” With the growth of the habit of depredation, the upper incisors increased from one geological period to another, whilst the lower incisors decreased and atrophied—a form of antithesis usually arising from a perverted f/w ratio. The two

incisives supérieures s'allongent considérablement en deux pieux tout droits, sans qu'à la vérité, on en puisse entrevoir l'usage ou la raison ! Enfin chez *Mastodon Americanus* (Pléistocène), l'atrophie des incisives inférieures est devenue complète : il n'en reste plus que deux chicots rudimentaires. Par contre la dystrophie dentaire se dépense fortement sur les incisives supérieures qui s'hypertrophient considérablement et deviennent, comme chez les Eléphants, les défenses monstrueuses, encombrantes et, parfaitement inutiles que nous connaissons à ces derniers.

More pertinently still from our point of view we learn :

Seuls, parmi les Proboscidiens, le Rameau des *Dinotherium* a conservé jusqu'au bout des défenses dont le rôle fonctionnel apparaît clairement. On devine, en effet, sans la moindre hésitation possible, l'usage de cette *pioche naturelle à deux fortes dents recourbées*, qu'elles représentent ; non moins qu'on discerne facilement celui du *double soc et du double contre de Palæomastodon*. C'est que chez *Dinotherium*, de même que chez *Palæomastodon*, les “défenses,” soi-disant, sont bien évidemment des *outils* et non pas des *armes*. Et c'est par un véritable abus de termes qu'on a appelé ces appareils dentaires des “défenses.” A moins de qualifier “armes” la pioche et la charrue du pacifique cultivateur !

In his ardour to defeat the “Biologistes-normaux,” the author goes so far as to confound the destructive instruments of the plant-carnivore with the pious implements of the agriculturist. But, if the “instruments” are not “arms,” they are not agricultural implements either. At least they have ceased to be such and now belong to the arsenal of robbery. Here, as elsewhere, the robbers' instruments are but “variations” of once truly useful utensils. In a Darwinian sense they have remained useful all along, but this can no longer be said on a duly sociological view of the matter, supported as this is by Comparative Pathology.

The hoe and the plough have not altered very greatly inasmuch as they have not lost their primitively honest character. And the same applies to organs; they become unrecognisable only in dishonesty. To some extent Dr. Larger's realisations are the same as mine, but, failing to be a consistent Bio-Economist, he is apt to fall from one extreme into the other, forgetting in particular that there is misuse as well as use and disuse, and a corresponding diathesis and a corresponding abnormality. He tells us, indeed:

les outils dont nous parlons, finissent, non seulement par perdre l'usage auxquels ils étaient primitivement destinés, mais par devenir un véritable embarras pour les animaux qui en sont porteurs!

The tusks merely continue to grow because the diathesis continues, *i.e.*, because the inordinate appetite, the misuse, continue. No wonder the elephant suffers from

une simple hypertrophie hyperplasique de la dentine. . . Quant à l'émail, on n'en peut, d'après Neuville, constater la présence au microscope que chez le jeune Eléphant: il cesse d'exister dès que l'animal avance en âge et il n'en reste quelques traces que tout-à-fait à la pointe. C'est là indubitablement la structure typique et caractéristique d'une dent dégénérée dont la formule est toujours celle-ci: "dentine, sans émail."

I would but add the following rider to "dentine sans émail": "animal sans symbiose."

The conclusion is now inevitable that Acromegaly is but the expression of a parasitic diathesis as affecting a species or a genus. Although Pathology has sometimes been acknowledged as to some extent representing the seamy side of Biology, yet Biologists have been exceedingly slow to make any practical application of this truth. Either they have dreaded getting on to slippery ground, or else they have too unscrutinisingly accepted as gospel some fundamental yet erroneous assumptions made by the pioneers of Biology. There cannot be the slightest doubt that these pioneers—too busy to deal with every aspect of the mighty problem of evolution—occasionally went sadly astray on physiological and "sociological" matters. As a striking example, in Darwin's remarkable introduction to *Variation*, there occurs a description of a vicious circle of depredation in which what is sociologically bad is quite obviously seen to be also physiologically bad, and which is yet supposed to illustrate the norm of "adaptation" by means of which varieties or "incipient species" eventually become converted into species. No one,

however, has so far seen fit to protest against the incongruity of attempting to base evolution upon such pathology as here entailed. Even Dr. Larger, as we have seen, was taken in by the "adaptation" view of Parasitism. This is what Darwin says (p. 6) :

There is, for instance, a fly (*Cecidomyia*) which deposits its eggs within the stamens of a *Scrophularia*, and secretes a poison which produces a gall, on which the larva feeds ; but there is another insect (*Misocampus*) which deposits its eggs within the body of the larva within the gall, and is thus nourished by its living prey ; so that here a hymenopterous insect depends on a dipterous insect, and this depends on its power of producing a monstrous growth in a particular organ of a particular plant. So it is, in a more or less plainly marked manner, in thousands and tens of thousands of cases, with the lowest as well as with the highest productions of nature.

And so it may well be, I should say, in a million cases without, for that matter, the phenomenon constituting aught but a pathological sequence—one that cannot possibly lead to progressive evolution. We must at last learn to distinguish the two paths in Biology : the symbiotic and the non- or anti-symbiotic, if the present muddle is to be avoided. The fly *Cecidomyia*, so we must argue, has abused its one time symbiotic power in order to gain certain expedient ends by means of short cuts. Its very power of producing the gall is but a travesty of its former symbiotic power, with its manifold and correlated capacities of stimulating the physiological economy of the plant. The fly now is merely poisonous to its food-plant and causes monstrosity, whereas it used to be helpful to the plant and furthered its welfare by counter-services. Powers of goodwill on either side, painfully established during long ages of correlated useful evolution, are now in course of being abused. In a symbiotic relation, as we have abundantly seen, both organisms thrive, and there is moreover a margin of benefit to the world of life. But in the above instance both organisms are injured : the plant by the wound, and the predaceous dipterous insect by becoming the soil of infection consequent upon its transgressions against the bio-social order of Nature. Darwin was astonished to find that a hymenopterous insect may be superior in the art of depredation to a dipterous one. But we may surely put the case down to a *corruptio optimi pessima*. If, as Darwin has elsewhere shown, those bees which indolently cut holes in the corolla instead of obtaining the nectar normally, become debauched,

then, *a fortiori*, we must expect to find a degradation in the case of parasitic propensities so pronounced as those of another Hymenopter: *Misocampus*. Here we have an almost entire, *i.e.*, racial, divorce from Symbiosis, whilst the debauched bee is but partially, *i.e.*, individually divorced.

The example used by Darwin to introduce his great work, rather serves to illustrate the way in which depredation is forever met by natural checks, the nett effect of which is to some extent to protect the "fundamental capitalist," the indispensable plant. For the owners of unnatural appetites never fail to turn upon and to decimate each other, thus relieving the pressure on the useful types.

When all this is said, it becomes clear that there is no mysterious reason for the pathology of depredation. There is obviously the strongest possible sociological reason that depredation shall be checked and penalised wherever possible. Hence physiology, or, for that matter, any other "ology" or "otany," has to some extent to be subordinated to the need of protection *i.e.*, to social needs. It is, therefore, unfortunate that Naturalists of all descriptions persist in strenuously denying the actuality of sociological factors, and that the mere mention of a socio-physiological term such as "appetite" is enough to send a shiver through their ranks. They believe that such terms are not "sound," and, being unable to deal with the substance of their science, fondly imagine that they have at least a "sound" portion to work upon when they deal with the shadow. But without "sociology," all Biology is but half knowledge. It is devoutly to be hoped that Dr. Larger's work will provide an eye-opener, and that it will facilitate the spread of those wider sociological views for which I have contended.

CHAPTER II

" ARBOREAL MAN "

The little more and how much it is.

IF any reader is still unconvinced of the fundamental and universal importance of food as a determining factor in the achievement of evolutionary success, I would advise him to turn to Prof. Wood Jones's book on *Arboreal Man*, in connection with the present volume.

The author does not take by any means so strong a view as I do of this importance, and this renders his testimony all the more valuable when its relation to my views is seen.

As regards the author's main thesis, a publisher's note gives us the following information :

Put as concisely as possible, although the argument of the book does not readily admit of being summarised briefly, Dr. Wood Jones's theme is a demonstration of the fact that Man, the supreme product of Evolution, could only have been developed from animals which had their homes and spent much of their lives in trees ; the main point in the argument being that the descendants of primitive animals living on the ground were inevitably doomed to become quadrupeds, and so missed the chance of acquiring the upright posture which is one of Man's distinctive attributes, at the same time paying for more immediate advantages by losing for ever that invaluable organ, the hand. Stated in these crude terms, the matter might at first sight seem to be only a chapter, though an important one, in the story of Human Evolution ; but before the reader has progressed very far, he will begin to realise that the arboreal habitat is not merely one of the conditions, but the central and dominating factor in the whole process. Not that living in trees was in itself sufficient to determine the line of progress in an upward direction. Many classes of animals lived, as many still live, mainly in trees. Mr. Wood Jones, reasoning on lines which would delight the heart of M. Henri Bergson, shows how and why only one of these classes continuously achieved " the successful minimum of specialisation," and moved slowly but surely in a direction which ended in Man, and not in a Lemur or a Sloth.

We have already seen that mere expediency of adaptation is not in the end conducive to progressive evolution, and that the achievement of the " successful minimum of specialisation,"

i.e., normal specialisation, requires a definite symbiotic nexus with the plant—here again so obviously concerned, though apparently merely as a mechanical aid to animal evolution. The author, however, rather avoids these matters by taking "adaptations," "variations," "mutations"—in short change—for granted. He makes the following reservation, or plea of ignorance :

Change comes about in some way that is obvious ; by what channel or channels it comes about concerns the present inquiry but little. How it is transmitted once it came into being, how it is accumulated, perfected, and handed on are questions which, despite an enormous amount of work, and despite an accumulated literature of dogmatic, and sometimes unjustified assertion, are at present unknown. Without touching upon these problems it is proposed to examine the probable path by which the Primates and Man have originated, reviewing the influences that have probably reacted upon them, but leaving aside the questions as to how changes have come into being, and how such changes have been inherited.

This is at any rate getting some fundamental but inconvenient difficulties of explanation out of the way. But it is scarcely comprehensive treatment.

According to Prof. Wood Jones, the ideal limb of a land-living Vertebrate has to satisfy two somewhat antagonistic purposes : those of stability and of mobility.

There is an antagonism in this evolution between the advantage of elaborating the ancestral, and useful, mobility of the limb, and the need for the newly developed, and essential, quality of stability. It is in this antagonism of development needs that the great interest of the study lies.

As an example of an ideal primitive limb, the author instances that of the ordinary water newt, as we can watch it climbing aquatic plants for instance. When such a creature took to a terrestrial habitat, he thinks, the limbs had to do more than to propel forward : they had to adapt themselves to supporting the body and to carrying it sheer off the ground. The limbs now had to lift the body during the act of propulsion. There is thus a general evolution of "stability" over and above that of "mobility."

We should have to ask a number of questions, however, with regard to the physiological requisites of such an evolution. What class of animals—in-feeding or cross-feeding—was it that succeeded best in changing from an aquatic to a terrestrial habitat ? What was it that appealed to the aquatic animals in

making the attempt to leave the water at all? What biological factors proved helpful, and what kind of physiological groundwork was it on the whole that, even apart from all volition, prepared the way to the emergence of progressive terrestrial adaptation?

Of the Amphibians, which play so great a part in Prof. Wood Jones's study, we know that the tadpoles are mostly cross-feeders (feeding largely on algæ). The Batrachians, moreover, excel by a comparatively high degree of parental sacrifice; all of which is of the highest physiological importance. Many Amphibians have remained strict cross-feeders to this day. We may conclude that in the case of aquatic cross-feeders, a successful evolution of the limbs was powerfully supported by an auspicious *f/w* ratio, entailing balance and orientation generally. To obtain the fullest biological support, whilst yet remaining moderate and balanced, this we have found to be the great pre-requisite of progressive evolution, and there is nothing in Anatomy to invalidate our conclusion. Such desiderata we have found to be in the path of Symbiosis and of Symbiosis alone.

In the absence of a Qualitative Biology to enlighten us with regard to what constitutes "normal specialisation," or even normal physiological or biological development, the author quite naturally is confined to the records of Palæontology as, to him, the only likely sources of information with regard to origins. Above all he points to the curious group of animals known as the Therapsida, which, "presenting a blend of primitive reptilian and primitive mammalian characters, flourished in the Triassic period."

And he says further: "It was, according to Broom, among the South African members of the Therapsida especially that the limbs became supporting organs, and he has said very definitely that "when the Therapsidian took to walking with its feet underneath and its body off the ground it first became possible for it to become a warm-blooded animal." The change that we have been picturing was, therefore, one which took place very far back in the geological past; and, according to Broom, the supporting limb and the mammalian possibilities made their appearance together, the one being dependent upon the other. The characters of the supporting limb as opposed to the purely propelling, but not supporting, limb, are so definite that there should be but little hesitation on the part of an anatomist in assigning the proper functions to the limbs of any extinct form."

This, however, tells us little about the "how" of the Therapsidian achievement. In a trice we are confronted by a "blend of primitive reptilian and primitive mammalian characters," by a type which apparently flourished exceedingly after the manner of "dominant" races. Whence did the Therapsida derive their dominance and power to support their bodies by the limbs? We shall not be far wrong in assuming that the source was the symbiotic plant. The mammalian character is a monument to partnership—partnership so far as physiological and special sexual arrangements are concerned and founded in turn upon biological partnership, *i.e.*, as between animal and plant. These factors alone are certain; all else is uncertain. What the particular plants were with which the Therapsida or their ancestors lived in partnership, is for Palæontology to say. The discovery of these Triassic plants, if not already made, should not prove too difficult a feat to accomplish.

If it had not been in the first place that the finer allurements of the plant's products had appealed to the corresponding senses of the Therapsida, they could scarcely have been abidingly and successfully attracted to the branches of the trees. Nor, without the vital pabulum there obtainable, would they have been able to shoulder the burdens and sacrifices incumbent upon mammalian life. The blend of good characters in the Therapsida, we may confidently believe, was not due to a coincidence; but it was due to the prevalence of comparatively high forms of Symbiosis.

The Therapsida, in approaching the mammalian status, were not, we may assume, after the "graces of life." And if it be not purely their "slow willing" that has produced the advance, we can only say that specially favourable physiological conditions prevailed in their case, such, in fact, as we have seen to result from progressive Symbiosis. We may say—apparently in accordance with Prof. Wood Jones's own intuitions—that "right" function produced the good result. It seems a pity that "partnership" as a means of progressive change has not yet apparently found a place in Prof. Wood Jones's scheme. In *Symbiogenesis* I have referred to Darwin's statement that "the brain must be bathed by warm blood in order to be highly active, and this implies aerial respiration," and I have there endeavoured to show that an important connection exists between respiration and food. The better the food—bio-economically considered—the better the respiration. It has been

found that the oxidasic power of an organism varies with the magnitude of its respiratory exchanges (H. M. Vernon), which is saying in other words that it varies with the organism's bio-economic exchanges of services generally, *i.e.*, as between animal and plant. A symbiotic relation, we may take it, is exceedingly favourable to auspicious, *i.e.*, "normal" respiratory exchanges, such as count in progressive physiological and, ultimately, in anatomical transformation. It is obvious that the chances of successful Symbiosis upon the land are greatly enhanced if the candidate for the terrestrial life already practised a tolerable degree of Symbiosis in the water. And we know that in what may be styled "aquatic Symbiosis" respiratory exchanges play a great rôle. The respiratory activities of Algæ and other water plants render the water hospitable for animals, many of which—Coelenterates, Crustaceans, Molluscs—live in close Symbiosis with those plants, which, in turn, make use of the animal spare products.

We are told that :

Looking broadly at the Mammals, we may say that the preservation and elaboration of the inherited mobility of the fore-limb is an essential for the culmination of evolution. We may also say that this preservation of mobility must start very early, before ancestral mobility had become lost in the development of stability ; and that the most successful Mammals must, by some means or other, have preserved and stereotyped this mobility almost at the outset of their mammalian career. Again, we may say that two distinct lines have been followed. Some mammals have perfected the new, and mammalian, demand for stability ; and others have retained a primitive mobility in, at least, the fore-limb. It is the latter which have been successful and have become dominant. The problem we are attempting to solve is : Why have some mammals retained this primitive feature of mobility of the fore-limb, and why have these same Mammals become more successful in the struggle of evolution ?

My answer is that the "culmination of evolution" consisted in the main in the perfection of the mutual relation between the highest forms of animals and plants. To be a Mammal is *ipso facto* to be emancipated from much that would otherwise militate against high serviceability in Symbiosis. But there are different degrees of Symbiosis, and some mammals, as we have seen, have perfected Symbiosis more than others. They are those which have been at once most serviceable to the higher plants, and also most temperate in their habits.

Broadly viewed, then, the two "paths" are determined by

two different appetites : one refined and temperate, and the other comparatively coarse and indiscriminate.

Whilst engaged in giving the lie to the teaching of modern orthodox anatomy and anthropology that man had evolved from a quadrupedal pronograde mammalian stage, the author tells us that it was the arboreal habit which saved the particular Mammalian stock which culminated in Man from becoming four-footed pronogrades. For the details of this teaching I must refer the reader to the book itself. In endeavouring to draw a picture of his hypothetical primitive Mammal, taking, not to a terrestrial but to an arboreal life, the author offers, however, the following interesting remarks :

The ability which such a primitive Mammal would have for climbing might perhaps be gauged by having regard for that skill in clambering which is manifested in the tailed Amphibians, a skill which we must remember develops within the limits of their own Phylum (in the Tree Frogs) into perhaps the most perfected tree-climbing displayed in the Vertebrate series. It may seem a long way to go back when attempting to unravel the influences of tree-climbing among the Primates, to appeal to the clambering activities of the water-newt. And yet the anatomical condition of the limbs of Man demands a shifting backward of the inquiry to some such stage as this. I believe that the truest picture of the evolution of Primate climbing starts with such a scene as we are depicting now. The method of this amphibian or reptilian clambering must be appreciated, for, as we shall see, climbing may be conducted in several different ways ; and the particular method practised by any animal may serve to date the evolutionary stage at which the habit was adopted. An Amphibian, or unspecialised Reptile, ascends an obstacle by clambering up ; its feet are applied to the surface of the obstacle up which it clambers. It makes no attempt to obtain a grip by nails or claws, but it trusts merely to the apposition of its feet to the surface to which it clings, and when this fails the animal falls.

Two points must be especially noticed. As its progress continues, it repeatedly reaches ahead with one or other of its fore-limbs for a new hold, and whilst doing this its body weight is temporarily thrown upon its hind-limbs. And, again, in reaching out its fore-limb, the freedom of rotation possessed by the second segment of the limb allows the animal to apply the palmar surface of its " hand " against any new hold which may present itself at almost any angle.

From such a humble beginning great developments are possible ; and here we may observe that, without the apprenticeship served in this lowly clambering, short cuts to tree-climbing have never attained the same ultimate perfection. As arboreal life becomes more complete, the search for a new foot-hold will become a far more exacting business than it is in the mere clambering we have pictured. The more exacting this search becomes, the more will there tend to be developed that most important

factor—the specialisation of the functions of the fore and hind limbs. While the animal reaches about with its fore-limb, the hind-limb becomes the supporting organ. With the evolution of this process there comes about a final liberation of the fore-limb from any such servile function as supporting the weight of the body; it becomes a free organ full of possibilities, and already capable of many things. This process I am terming *the emancipation of the fore-limb*, and its importance as an evolutionary factor appears to me to be enormous.

This plausible, if hurried, account of man's evolution, I believe, on the whole corroborates the view here set forth, namely, that it was fundamentally the search for the vital spare products of the higher plant which prompted the essential emancipation of the fore-limb. When we are made to visualise a "non-specialised" animal, depending little upon "nails and claws," we know that we are not far removed from a symbiotic animal. We are introduced to an inoffensive, plastic, yet wisely conservative creature, exhibiting a well-balanced division of labour and right proportions down to the very details of organisation—the advantages incidental upon symbiotic relations of a high order, associated, as a matter of course, with non-felonious food-getting. We conclude that it was the ennobling appetite with all it entailed, that ensured the mobility and emancipation of the fore-limb and saved it from "servile function."

As already noted, numerous Amphibians are characterised by cross-feeding habits. That short-cuts to tree-climbing have never been really successful, recalls the similar ill-success of some Hymenoptera in trying to obtain the nectar by short-cuts, in avoidance of Symbiosis, *e.g.*, by biting holes into the corolla.

In either case there is required, as the norm of life, an adaptation at once temperate and pregnant in bio-economic, *i.e.*, widely useful, consequences, and this cannot be achieved except by gradual, painstaking and honest specialisation.

Prof. Wood Jones cautions us against regarding the arboreal habit *per se*, or even the emancipated fore-limb, as the talisman; and, from what he says on the subject, it is clear that Carnivorism is not apt to confer the happy mean of adaptation. Thus we learn:

Other mammalian stocks have taken to an arboreal habit; but they have taken to it after varied periods of quadrupedal life. They have taken to it too late to derive the full benefits from it, for they took to it with the fore-limbs already deprived of some of their inherited mobility. Such animals never become perfect tree-climbers. They may acquire an extraordinary skill in running about the branches of trees, as many Rodents

do, or they may even climb in the proper sense of the word, but in this climbing the grip is not obtained by the application of the palmar surface of the hand, but by the hook-like action of claws and nails ; this method is practised by many of the Carnivora. The maximum of possibilities is not attainable in any of these cases. It is not enough to have a thoroughly emancipated fore-limb, it is not enough to be thoroughly arboreal. It was a combination of *seemingly humble and unimportant* circumstances, acting at the very dawn of mammalian life, which permitted the emancipation of an unmodified fore-limb in a certain stock, and so laid the direct path for the evolution of the highest Mammals and Man. (Italics mine.)

But, in point of Bio-sociality, carnivora usually climb trees for a totally different purpose from that animating symbiotic animals. Their “ industry ” is not one requiring honest specialisation, and, in the absence of such, they become “ over specialised,” tending towards “ Contre-Evolution.” Their appetite lures them to mere expediency of specialisation, and this is not enough to achieve the highest results in evolution. It is not enough, I should say, to possess an appetite. What is needed, is that happy mean of appetite which is most consistent with the performance of patient and systematic services and duties. And an appetite thus “ controlled ” is yet most likely to be rewarded by a complete diet—one that powerfully, if unobtrusively, aids the realisation of a maximum of possibilities. Is there anything to contradict these conclusions ? Is there any other explanation which accounts with equal cogency for the facts confronting us here ?

In support of my contention that it was originally and most potently the attraction and also the high physiological value of the spare products of the trees which determined the evolution of arboreal habits, I would instance the case of so lowly a creature as *Birgus latro*, a crab which climbs trees in search of Pandanus and other fruits, and even of cocoanuts. This Decapod was evidently allured and assisted to a terrestrial habitat by a cross-feeding taste, and with the aid of the aforesaid diet it has managed to live permanently upon the land. *Birgus latro* shows a comparatively high perfection of respiratory arrangements, and, altogether, the order of the Decapods includes the highest forms of the entire class of the Crustaceans. Other things equal, therefore, cross-feeding represents everywhere the superior habit of life, one that is pregnant with possibilities of progressive evolution.

Unwittingly, Prof. Wood Jones bears witness to the same truth, as when he says :

It is a very remarkable fact that in the numerical development of the individual bones which compose the separate fingers, the Chelonians (Tortoises and Turtles) are the match of Man and his nearest mammalian neighbours. There is evidently something extraordinarily primitive about the hand that has been preserved and passed on to Man ; but like the primitive rotating forearm, this primitive, simple and unspecialised five-fingered hand is full of possibilities.

And again :

It is a fact which cannot be ignored, that in the details of its skeletal elements, the fore-limb of the highest of the Mammals finds its likeness among living Vertebrates in such a primitive creature as the tortoise.

The significance of the parallelism, in my opinion, is this, that in either case the early ancestors were characterised by a similar *f/w* ratio, and that there was a persistence of similar, if not identical, temperate and cross-feeding habits. There is no doubt that the Chelonians are now, and have been in the past, largely cross-feeders. To this day by far the larger numbers are herbivorous or frugivorous, and, like other cross-feeders, they are remarkable for their longevity and retention of life. They can exist for months without eating. The tortoises feed chiefly on leaves, berries and lichens, and many turtles are strictly herbivorous, feeding upon algæ and *Zostera marina*, the edible "Dulse," growing on the coast of Florida.

In delineating the development of his hypothetical primitive Mammal, the author makes a passing allusion to food :

The animal, from grasping branches, may readily turn to grasping leaves and fruit—it may learn to grasp its food in its hand. As a sequel it may learn to convey the food so grasped to its mouth with its hand and so become a hand-feeder. It may take to grasping other objects which come in its way. These objects may be useful for food or they may not ; but the animal will learn to form an estimate of the object grasped. As a sequel it may learn to feel, and to test novel objects with its hand. Again, the mother may learn to grasp her off-spring in the precarious circumstance of an arboreal infancy ; and she may adopt the habit of carrying and nursing her baby. All these things are of vast importance.

We have already seen that such and similar psychological and sociological advantages as here alluded to, depend largely upon the kind and quality of the food and upon the methods of getting it. We have found that psychological and sociological evolution require a perennial demand for restraint such as is actually entailed in the symbiotic relation. Whether an animal

is after leaves or after fruit, makes a great difference, nay, it is well known that conspicuous physiological and anatomical differences arise even with differences of " soft " or " hard " feeding among allied frugivorous birds for instance. All such differences are associated with vitally important differences of service in Symbiosis, with their far-reaching reactions upon the evolution of the organism.

Fruit-eating animals, among whom man is included, are the friends of the fruit-tree. They do not, for instance, crunch up the fruit, kernel and all, as a grazing animal would do. They are more temperate and more symbiotic in disposition. They work in harmony with the fruit-producing plant. And they like the bright colours and sweet scents (which, according to Mr. E. Kay Robinson, are danger signals to the eaters of green-stuff) because they indicate that their favourite food is ripe and ready to be eaten. Grazing and browsing animals, however, are generally the enemies of the higher plant, and Mr. E. Kay Robinson says :

They are afraid of bright colours ; so the fruits are brightly coloured. They dislike scents ; so the fruits are scented. The colours and scents of fruits have, so far as they are concerned the same meaning as the colours and scents of flowers.

However this may be, we may feel certain that habitual biological use or misuse in course of time is replete with physiological and anatomical reactions. The buffalo grass has gradually disappeared from the prairies, which are no longer roamed by herds of buffaloes. The buffalo grazed down all the rivals of the buffalo grass, and the latter, being especially adapted to survive in such circumstances, flourished exceedingly. With the departure of the buffaloes, however, the other plants are having their turn of prosperity, and the buffalo grass is not adapted to compete with them on equal terms.

It may thus be said that by their food-adaptations animals determine to a large extent their own evolution. Who will doubt that it has always been thus ? We are too apt to think that food counts for very little, so long as there is enough of it. It is one of those " seemingly humble and unimportant " factors that yet matters most in evolution. We are confirmed in our prejudice by the observation that domesticated animals devour almost anything they can obtain. I have indeed been taken to task for my cross-feeding thesis by a learned critic, in view of the

omnivorous tastes of our domesticated "productions." But, as Mr. Kay Robinson says (*Country-Side*, 10.4.1909) :

You cannot attach decisive importance to the conduct of domesticated animals. I am quite sure that turpentine is not a natural food for horses ; yet in Norfolk the farm horses used to spend a large part of their leisure wandering round the garden railings and trying to nibble the turpentine branches of the Australian pines. A well-fed domesticated animal always hungers for novelty in food ; and I expect that turpentine or the mixed tastes of Alpine flowers are to the fat cart horses what caviare and curry are to us. The goats which ate the scarlet anemones—though I suspect they ate them before any scarlet could be seen—were domesticated goats, which will devour newspapers with relish. In my youth I knew a goat which had a passionate liking for tobacco ; and once I allowed it to eat an ounce packet, paper-wrapper and all. It simply loved me after that treat. I think, therefore, that we must discount the goat and other domesticated animals as guides to natural conditions, although in some instances their conduct may give us a clue to the past.

We may confidently conclude that if animals are often lured to their doom by their appetites, it is largely by their appetites that they are led to their "lessons" and "industries." To possess thoroughly emancipated fore-limbs, or even to have become thoroughly arboreal, could indeed not have been enough for the purposes of progressive evolution, if such emancipation was only contrived for biologically illegitimate purposes. For, as we have seen, genuine evolution is not furthered by methods of mere expediency, but only by wide and bio-economic usefulness, entailing a maximum of symbiotic correspondences. The combination of "seemingly humble and unimportant circumstances," spoken of by the author, as acting at the very dawn of mammalian life, is none other, I believe, than the symbiotic connection between plant and animal. This is how Prof. Wood Jones tries to account for those early circumstances :

The arboreal habit (he says), conferred its benefits by emancipating the fore-limb from the duties of support and progression, and, by differentiating its functions from that of the hind-limb, it saved the animal from becoming quadrupedal. In differentiating the functions of the two sets of limbs, the animal gains a great deal. Some animals, one might almost say, have gone too far in adapting themselves to the arboreal habit. An animal, saved by the arboreal habit from becoming quadrupedal, does not gain the maximum of the benefits derivable from its new mode of life, if it is saved from this fate only to become quadrumanous. Four feet do not lead far in the struggle for mammalian supremacy, four hands do not lead a great deal farther. It was the differentiation into two hands and two feet that provided the great strength of the stock from which Man arose. The active specialisation of the fore-limb did much,

but it could not do all, without the accompanying passive specialisation of the hind-limb. Mere ability in climbing, which usurped the power of any real ability to walk, was but a poor accomplishment, for to complete the whole story of evolution the animal which climbed up the tree had still to walk down—and the Old-World apes still show in caricature how this was done.

In other words, given auspicious (physiological and correlated) mechanical conditions, a highly beneficial “reciprocal differentiation” could take place between fore and hind limbs—a high form of “domestic” Symbiosis, which, as we have seen, indispensably depends upon biological Symbiosis.

Service and progress through Symbiosis being the chief aims of Nature, there was no need that all the limbs should specialise for the grasping and handling of the food. Enough if the fore-limb so excelled. The hind-limb could not do better than adapt itself reciprocally.

Prof. Wood Jones’s explanation, no doubt, is still too purely anatomical. At best we only dimly perceive that some auspicious extra factor has favoured the reciprocal differentiation of the members as pictured. What that factor is, however, does not emerge. It was not the fresh air of the tree-tops, for that was accessible to those which turned quadrumanous quite as well as to those animals for which a happier destiny was to be provided. Was it Luck? Or was it Cunning? The case becomes intelligible if we regard it as representing a thorough and advanced application of the “law of the members.” Man’s progenitor apparently was one who excelled in biological righteousness, which gave scope to a number of beneficial principles, physiological, anatomical and sociological, to become operative towards the exaltation of his type.

With regard to the evolution of the hind-limb, the author thinks that in its case stability became substituted at an early date for mobility, telling us that

environmental conditions could not combine to free the hind-limb of its duty of supporting the body weight and yet preserve it in full functional activity; the arboreal habit did this for the fore-limb, but there was no life circumstance that could do the same thing for the hind-limb.

I should say that the main contingencies of life were such as to render unnecessary a great specialisation of the hind-limb. All that was necessary was that it remained in due complementary relation to the fore-limb, which, being emancipated according

to Symbiosis, and being more directly connected with the brain, was destined to become the predominant partner.

Once again we meet with the food factor in connection with the "recession of the snout region," and we are told:

It may be said on broad lines that throughout the whole of the animal kingdom the mouth parts show a development depending upon the nature of the *animal's food* and the *method of taking it*. If it is the hand which becomes the grasping organ, the mouth and the anatomical structures connected with it need no longer be developed in any special way to carry on this function. The food-grasping power of the primate hand renders unnecessary the development of grasping lips and a long series of grasping teeth. Again, the fact that the food once grasped by the hand is conveyed by the hand to the mouth renders the mouth and its associated parts merely an organ for dealing with food already grasped and carried to it. A mouth merely adapted for the reception of food already grasped and brought to it is a structure very different from a mouth adapted for the purposes of reaching out for food, seizing the food so reached, and subsequently dealing with it. (*Italics mine.*)

Everything depends upon the "if," and the "if" evidently depends upon the appetites of the creature. It was admitted by Darwin in the case of the short-snouted, tree-climbing vegetarian lizard, the *Amblyrhynchus* of the Galapagos Archipelago, that such and similar short-snoutedness amongst tortoises, many of which feed on fruits and berries, depended upon "herbivorous appetites." The essential condition of progressive anatomy is satisfactorily fulfilled only with symbiotic cross-feeding; and this is entirely omitted by Prof. Wood Jones. As, however, the teeth are referred to, it is as well again to point out that Carnivorism could never at any time have produced the desirable development. It was reported in *Nature*, 30.5.18, that there is a remarkable uniformity in the Anatomy of flesh-eating Dinosaurs of Mesozoic times, whether they are early or late, small or gigantic. They all had large hindquarters for bipedal walking, a long tail, very small mobile fore-limbs, and a more or less regular series of sabre-like teeth.

No one would believe that from such a carnivorous Dinosaur, though it walked on its hind-legs, and though even possessed of mobile fore-limbs, any progressive evolutionary development was to be expected. The shape of its teeth alone, as determined by the animal's feeding habits, would have precluded such development.

(True, Sir E. Ray Lankester is of opinion that it is now

certain that from reptiles similar to the Dinosaur Iguanodon, the teeth of which have been found in some particulars to be like those of the little living lizard from South America, called the Iguan, the Birds have been derived.* But this Dinosaur was at any rate herbivorous, and Sir Edwin's conclusion, if correct, in reality points to a cross-feeding ancestry of the Birds.) However this may be, it is certain that the " food-grasping power of the Primate hand," which rendered unnecessary " the development of grasping lips and a long series of grasping teeth," depended for its evolution upon temperate cross-feeding habits. Once the Primate had, in virtue of " right " feeding habits, obtained a good start, the symbiotic momentum easily carried him further along the path of progressive development. Prof. Wood Jones says too little about the nature of the food and overlooks the importance of the " biological " method of getting it. He confines himself to the mechanical side of the matter, and continues thus :

When the mouth is the food-obtaining organ, there is a necessity for its situation being advanced from the face, and especially that part of the face in which the eyes are situated. A long snout with a mouth opening far in advance of the eyes is a necessity in any animal which used its mouth alone, in all the processes of obtaining food. The grazing herbivores must carry their food-getting mouth far in advance of their eyes. The long face of the horse may serve as a familiar example. The animals which catch insects must have a similar structure, and the " snouty " insectivorous Shrews are typical of such animals. The more the forelimbs serve to obtain or to hold the food, the less is this snout developed, and I am terming the change which hand-feeding produces *the recession of the snout region*. In herbivorous animals the transition is very easily seen ; the long faced horse may be contrasted (solely from the point of view of this function) with the short-faced squirrel which holds food between its fore-paws. In carnivorous animals and mixed feeders another factor comes in, for the mouth may be used, not only for grasping, but for killing the food, or the fore-limb may take over this function in part.

The grazing herbivores and the insectivorous Shrews—although some of the latter, such as the *Tupaia*, are arboreal—are, therefore, not in the line of progressive evolution. I have already insisted on the inferiority of such types on the ground of their relative backwardness in Symbiosis, and, as regards more specially the latter, because of their in-feeding habits. The anticlimax in snout development as between the puny fruitarian and seed-distributing squirrel and the large-sized but plant-carnivorous horse, is striking enough in illustration of the

**Extinct Animals*, pp. 200-203.

superiority of a relation of tolerable Symbiosis to one that is merely of the nature of an "unholy alliance," albeit the difference is still between cross-feeders.

If, as the author says, "in carnivorous animals and mixed feeders another factor comes in," this is only too true. It is the adaptation of the mouth to "killing," which constitutes the new and complicating factor, although the author seems very chary of allowing the full significance of the matter. The fact of "killing" altogether alters the case, and apart from the author's data, there are other and some very far-reaching injurious reactions of sanguinary habits to be borne in mind. There are, for example, the long fangs, entailing, because of their exorbitant demand of blood-supply, a much reduced brain; there are the ferocity and thriftlessness of the beast, unfitting it for the industrious and the social life; the diminished Phagocytosis and consequent impoverishment of the blood—all testifying that bestiality is on all counts the surest bar to progress. I have already instanced the fact that food borne infection is very common amongst Carnivora and Omnivora. Our food-plants are not attacked by any micro-organisms pathogenic to man or to animals; but our domestic slaves, which we kill for food, suffer from bacterial infection, and this is communicable to man. All of which is calculated to throw light on the way in which "killing" is pregnant with injurious reactions upon the predatory organism. Again, there is the fact, established by Richet and other Physiologists, that fruit and vegetables—with the exception of a few over-cultivated ones—never give rise to "Alimentary Anaphylaxis" (the dietary equivalent of serum-disease), whilst flesh foods often produce the same distressing symptoms upon body and mind as are known frequently to result from a direct introduction of protein poisons into the blood, which again shows the case of the in-feeder in general to be very inferior to that of the cross-feeder. Facts such as these, I consider as of almost inconceivable importance in evolutionary anthropology. They far outweigh anything of evolutionary import that can be advanced on merely anatomical grounds. As regards the recession of the jaws and the more or less connected reduction of the tooth series, we are further told:

With the business of hand-feeding, Man has gone a great deal farther than any other member of the Primates, and that comparatively modern development—civilised Man—has gone still farther. The highest Primates

select their food with their hands, they even do more than this, for, to a certain extent, they prepare it for eating, with their hands. But this preparation, though an enormous stride, does not go to very great lengths beyond peeling a banana or husking a thin-shelled nut with the fingers ; for anything much more exacting the teeth are requisitioned. We have seen the amount of work that the hands have already saved the teeth in the evolution of an arboreal stock, and there is obviously a tendency in the highest apes for the hands to assume further duties. Man has applied his brain and his mobile hands more fully to this problem, and he has saved his teeth to the utmost limits, but has made a sorry bargain.

The evolutionary problem, then, was this : how was a cross-feeding species to apply the utmost amount of industry and of co-operation to the treatment (and also to the multiplication and improvement) of the spare products of the higher plant.

Man (the author continues) has ground, husked, prepared, cleaned, and finally cooked his food. He has freed it from hard parts, and made it " tender " in every conceivable way.

Surely this applies in the first place to seeds, fruits and vegetable products generally. By becoming the ally of the respective plants, man has entered the path of great progress. In making his food too " tender," civilised man has overdone the success of his brain. The sorry " bargain," referred to by the author, consists in the loss of teeth owing to disuse, as he thinks. No doubt modern man sorely needs a more natural dietary. His inferiority with regard to power of repair is accounted for by his flesh-eating propensities, together with other concomitant evils. It is not so much use or disuse, as abuse that has played havoc with modern man's dentition, and the author fully admits that more primitive races show to advantage when compared to " highly civilised " man. Civilisation *per se* is no more to be blamed for the decay of the teeth than is the upright position of man to be lauded, as the author says, as one of man's greatest distinctions.

This praise of human uprightness has, without doubt, been carried to absurd extremes, so also has the tendency to ascribe to this same uprightness a multitude of human weaknesses and disabilities. This visceral uprightness is no new thing, the readjustment has been gradual, and some measure of it has been very long established. It is easy to overdo the praise of the poise. It is equally easy to overdo the condemnation of it as a cause of many ills.

I should say that it is equally easy to overdo the blame of civilisation in the matter of dental decay, which, no doubt, is more justly viewed as the result of wrong feeding habits.

It is worth noting here what the author avers with regard to what the arboreal life has done for the respiratory system of the Primate stock :

it has given them flat chests and flat backs, has brought about a greater degree of dependence upon the diaphragm as a mechanism of inspiration, and at the same time, has added to the mobile fore-limb an increased source of mobility in the muscles of the external respiratory system.

There is, therefore, ample compensation for the vicarious sacrifice of mobility on the part of the hind-limb. The compensatory advantage more than balances the loss, seeing that the evolution of the species generally is favourably determined by the sacrifice.

The recession of the snout is correlated with the liberation of the hand, and

the liberated hand takes on the duties of the snout, and the exchange is effected very completely and harmoniously, so that all those functions formerly discharged by the snout, are now carried on, and with far greater efficiency, by the hand. The physical changes are great and obvious, but as possibilities of progress in evolution they are trivial, compared with the new avenues opened up for cerebral development.

And the author continues thus :

The enormous difference which the translation of the receptive mechanism for touch impressions makes in animal economy is difficult to appreciate. Change of conduct, however, makes apparent the more striking lines of progress. The picture of the lowly animal which noses its way through life smelling with its nose, and examining with its snout all novel objects with which it comes in contact, is familiar to everyone, and is one that contrasts strongly with the behaviour of an animal that has become arboreal. Although it is a very long step to take, much may be learned by going straight to a Lemur and watching its treatment of novel objects. Here, handling obviously takes the place of nosing, although the scent test is by no means omitted, especially in all cases where the suitability of the object as an article of food is concerned. If *Nycticebus* is given some fruit which is new to it, it will hold it to its nose. It will also smell its hands, and if these tests produce no result, some animals will proceed to rub the fruit, or hammer it on the ground, in order to obtain the scent from a bruised or scraped surface. All this is done before any attempt is made to eat any unfamiliar object. Much the same behaviour is shown when the animal tests an object which is merely a novelty, and is not regarded as a possible article of food. The superiority of hand-tactile information is at once seen by watching such an animal, and the possibilities of education of this new touch organ are easily realised. Even before the power of grasp is developed, we may imagine the dawn stages of educational advances initiated by hand touch.

The picture drawn, in reality reveals the road to mental

evolution on the part of symbiotic cross-feeders. It is not for nothing that the author again instances fruits and fruit-eating species. What he has to say about " change of conduct," applies with special force to change of " biological " conduct, in which conduct moderation and refinement of feeding habits must be accorded pride of place. Very truly the author says :

The evolution is evidently harmonious in its details. The more the fore-limb becomes emancipated, the less is the hand called upon for menial duties which in other stocks necessitate the development of skin thickenings, pads, callosities, or hoofs. It is the freed hand which is permitted to become the sensitive hand which now, so to speak, goes in advance of the animal and feels its way as it climbs through life.

The freedom referred to is virtually that which Huxley appreciated, namely, that to do right, though here in the biological sense. Evidently the result cannot be obtained without a fairly high degree of " refinement " and restraint, without commensurate biological conduct. We have discovered that without a sufficiency of duly altruistic activities, the necessary refinement and restraint and the very stimulus to psychical progress are wanting, whilst there is wanting also the physiological groundwork requisite for a high degree of plasticity of the brain. Although this plasticity is a great factor in human evolution, Prof. Wood Jones would not seem to have made sufficient provision for it. He tells us :

The very fact that the sense of touch becomes lodged, to so large an extent, in the emancipated hand of the arboreal animal becomes a guarantee that this hand will be called upon to discharge its tactile function in a variety of ways. All sorts of uses, previously quite foreign to it, will be demanded of it in virtue of its possibilities as a tactile organ. The combination of the increasing tactile perceptions, and the freedom of movement, creates a condition which ultimately leads to the most important developments.

All this is quite true ; but we have found the author originating the refined sense of touch (in the emancipation of the hand), with the evident appeal made to the animal by the spare products of the plant, namely, fruits ; and the significance of this appeal is more than mechanical.

The whole case, in fact, is but an integral part of the correlated evolution of plant and animal.

The sensory stimuli (Professor Wood Jones goes on to say), streaming from the hand towards the central nervous system must become associated in the most intimate way with the motor impulses streaming to the mobile fingers.

In my view, there are required many delicate psychophysiological associative processes, which, for their effectiveness and permanence depend on a high symbiotic condition generally. One might say that these processes largely depend upon the Bio-Chemistry of the body ; but this, as we discovered, depends in turn upon the bio-economic behaviour of the species.

The incompleteness of Prof. Wood Jones's scheme becomes again apparent in the last chapter but one, where he is dealing with " the failures of arboreal life," and where he begins thus : " There would seem to be a general law applicable to animal adaptations — a law which we might term *the law of successful minimal adaptive specialisation.*"

The use of the word "successful" here seems rather a begging of the question, whilst even "specialisation," as I have said before, is rather vague. We have found, moreover, that the "over-specialisation" to be avoided by the organism, is in reality "mis-specialisation," *i.e.*, modification according to biological "misuse." If we are agreed that the organism exists neither by itself nor for itself, and cannot, hence, escape being a "specialist" of some sort, the question arises, how is it to become and to remain a "normal" specialist. "Successful minimal adaptive specialisation" is only another way of stating the accomplished fact, without explaining how it is done. We are a little nearer the truth if we say "moderation in all things," whence it is not a far cry to "symbiotic moderation," with the implied "symbiotic endeavour." The author here invokes the aid of "plasticity" and of the "environment." It is not disclosed, however, what it is that creates and ensures "plasticity," and it is but dimly hinted what scope there is through mutual service for specialisation in a very real, *i.e.*, a socio-physiological meaning of the word.

A plastic stock, given unlimited scope of development in varied environment, tends to differentiate. Different races will specialise towards the needs of their environment.

But, as I have said, the author has not sufficiently developed the theme of "sociological" specialisation ; he has failed to realise that a "plastic stock" is one that practises symbiotic cross-feeding, that to be symbiotically related to the animate environment, almost *ipso facto*, constitutes plasticity.

Different environments (he goes on to say), offer varying possibilities of education, expansion, and advance, but the full educational possibilities

are not necessarily grasped solely, or to the full, by the animal which becomes most completely specialised.

But we have concluded that the most ideal specialisation is that of the animal which is the most harmoniously and the most usefully inter-related to the rest of strenuous organic life ; and such an animal is by the very fact of this interaction precluded from making faulty adaptations.

The author here loses himself in the abysses of " Contre-Evolution," after the fashion of the " Biologiste naïf," and, after what has been said on the subject in previous chapters, I need not follow him further along this track. To one remark of his, however, I shall have to add a strong rider, namely, with regard to " specialisation to an exclusive diet."

Such a diet, he thinks, has proved the downfall of many a promising animal type, and he instances a " specialisation " for blood-sucking, or for ant-eating—in significant contrast to those other feeding habits which, on my interpretation, stand out prominently throughout the book as favourable to success, namely, those which I have termed " cross-feeding." Obviously this matter cannot be treated in a discursive manner, and without answering the questions : what constitutes an " exclusive," and what a " normal " or " ideal " diet. The author's predicament, of course, is that nutrition is still largely a *terra incognita* of science. *De hoc multi multa, omnis aliquid, nemo satis.*

With almost incredible levity, he makes the transition from the unsuccessful blood-sucker and the equally unsuccessful ant-eater to the immensely successful Primate stock, the triumph of which is suddenly to be accounted for by " non-specialisation in diet," *i.e.*, by a combination of carnivorism with frugivorism or herbivorism :

The Primate and human stock has not been led astray in this direction ; for it has preserved throughout that well-balanced habit of dietary, only to be termed omnivorous.

It is satisfactory to find that it has at last dawned upon the author that food-adaptation is all-important. It is at least a good beginning. But it seems rather arbitrary, if not unkind, to saddle the Primate stock with omnivorism, when, throughout the story, the most was made, and rightly so, of its successful ventures and transactions with fruits and seeds. I strongly demur to the view that an omnivorous diet is a " well-balanced habit of dietary," which is based upon prejudice rather than

upon science. Though the omnivore be less divorced from Symbiosis than the blood-sucker, yet his promiscuous diet is little calculated to preserve a "successful minimum of specialisation"—the "all, but no more than is necessary," which depends upon an untarnished symbiotic relation. There is no evidence whatever that a diet of seeds, nuts and fruits, which, on the author's own outline, we may assume the Primate stock to have enjoyed, has ever produced the downfall of an animal race. Quite the contrary; the available evidence points to the conclusion that such a diet constitutes the ideal norm for the achievement of the highest progress. Evidently, however, the idea that some kind of righteousness has characterised the human stock, has taken possession of the author. He says:

It is not likely that a habitat so attractive and so universally present as the tree-tops would fail to be abused by some members of the stocks which have taken possession of it. It is the distinction of the human stock—a distinction to which we have had frequent occasion to allude—that it never became the slave of its arboreal environment, for it became adapted to tree life in a strictly tempered manner, and it specialised to the successful minimum degree.

This, especially after what has been conceded with regard to diet, is but another way of saying that the distinction of the Primate stock consisted in a steady adherence to symbiotic moderation, which rather clashes with the previously expressed surmise that it was omnivorism, a partly predatory life, that conferred the saving grace upon the stock. It is no particular distinction, on the author's own showing, to be arboreal; and it is surely much less of a distinction to be omnivorous. But if there had to be a distinction, consisting in temperate behaviour, at all, it may well have been that of frugivorism, which has so much in its favour, as I believe to have to some extent shown.

Is Prof. Wood Jones really prepared to say that omnivorism is a means to the achievement of a successful minimum of specialisation? This would involve him in contradictions with some of his own teachings. For he shows failure of progress though with a perfect adaptation to omnivorism, and though even with a previous apprenticeship in arboreal life, as, for instance, in the case of the flying mammals. He tells us:

A flying animal knows no limits of habitat or environment; geographical barriers, which limit the activity and spread of the stock from which it sprang, offer no unsurmountable boundaries to its enterprises. Indeed, the geographical distribution of the *Cheiroptera* demonstrates the reality

of this advantage. The power of flight, whilst offering an abundant change of habitat, affords also an almost unlimited range of dietary ; it facilitates escape from enemies, and provides a ready means of avoiding local overcrowding, rivalry, or temporary local adversity. All these things are assets—enormous assets—in the preservation and multiplication of the type ; and the specific richness, the enormous numbers of individuals, and world-wide distribution of the Bats, are evidence of this.

Yet, when all this is said, there is a great “ but ” :

It must be remembered that, despite the undoubted successes of the flying Mammals in these limited directions, there has been an evolutionary stasis in the group extending over a very long geological period. They have obviously gained their freedom and their specific plasticity at the expense of some very vital evolutionary asset. The thing which they have lost in taking to an aerial life is the very thing which they won in their arboreal life, the factor which made their aerial enterprises possible—the emancipation of the fore-limb. Their fore-limbs have become purely specialised as “ wings ; ” they are no longer useful for grasping, for touch, for examination and for all the other functions which we have seen so essential in the final education of the neopallium which makes for real evolutionary progress. No matter from what sources, and by what routes, the whole of the flying Mammals comprised within the limits of the order *Cheiroptera* were derived, we may regard them all as animals which, having sacrificed the very valuable freedom of the fore-limb to the powers of flight, had flourished exceedingly as a consequence of their enterprise, but had progressed but little in real evolution, since the very factor which enabled them to take their momentous step had been altogether absorbed in taking the step.

Even the vastest possibilities of omnivorism, therefore, are not enough to open a path of progress. On the contrary, the more assured the omnivorism, the more certain is the loss of a “ vital evolutionary asset.” It is possible, of course, that the flying mammals were driven by some adversity to an aerial habitat ; but it is far more likely that their failure arose through faulty food-adaptation of some sort, be it only through unsymbiotic use of plant products. And I would lay it down that wherever in evolution we meet with a failure of *retinens vestigia famæ*, we may conclude that the ancestors of the order have either failed in symbiotic behaviour towards the plant, or, worse still, have sold their birthright for a *potage au gras*.

We have no reason for thinking that feeding upon slugs, worms, larvæ, insects, etc., calls for any great æsthetically or educationally valuable exercises on the part of the limbs. Nor are such habits conducive to a high mutual specialisation of the limbs ; nor to a recession of the snout region. On the contrary, inasmuch as they are in opposition to the law of concord in Nature, they

are prone to have inhibiting and unbalancing effects, apt to introduce components of "over," rather than of normal specialisation, of "contre" rather than of progressive evolution. The craving for such food is in itself proof positive that short cuts and felonious excursions rather than legitimate roads and physiological righteousness are desiderated by the respective species. We have, however, every reason for thinking, on the other hand, as has been shown in the foregoing pages, that the highest kind of development is associated with that kind of food, the getting of which is legitimised by uncounted ages of mutual evolution of animals and plants, and entails some kind of counter-service and corresponding equipment for service on the part of the animal. Complete diet, complete work, and complete evolution go together—"complete" implying all, but no more, than is necessary in the highest interest of "organic civilisation."

I believe I have to some extent shown that cross-feeding was primitive, and that, inasmuch as it is associated with useful partnership, it is indeed of the very essence of progressive evolution. I have emphasised that if, according to Prof. Wood Jones, in the details of its skeletal elements, the fore-limb of the highest of the mammals finds its likeness among living Vertebrates in such a modest, sociable and inoffensive creature as the tortoise—remarkable also for its short-snoutedness—this animal belongs to an essentially cross-feeding stock. There is much inherent probability, therefore, that the chief distinction of the human stock consisted in long continued faithfulness to the primitive virtue of symbiotic cross-feeding. This would be in complete agreement with man's primitive anatomical simplicity as pictured by Prof. Wood Jones in his *The Problem of Man's Ancestry*, where he states (p. 31) that

No monkey or anthropoid ape approaches near to man in the primitive simplicity of the nasal bones. The structure of the back wall of the orbit, the "metopic" suture, the form of the jugal bone, the condition of the internal pterygoid plate, the teeth, etc., all tell the same story—that the human skull is built upon remarkably primitive mammalian lines, which have been departed from in some degree by all monkeys and apes. The human skeleton, especially in its variations, shows exactly the same condition. As for muscles, man is wonderfully distinguished by the retention of primitive features lost in the rest of the Primates.

No doubt, the monkeys had not remained as wisely conservative in the matter of cross-feeding as had the primitive human stock, and in *Arboreal Man*, Prof. Wood Jones tells us that the

monkeys and lemurs are wont to catch, to tear to pieces, and to devour other animals, *i.e.*, that they are occasional in-feeders, as they undoubtedly, even as cross-feeders, are given to the unsymbiotic practice of crunching up the fruits, kernel and all. Man's superiority, then, was due to the fact that he was less bestial than the monkeys. Otherwise expressed, he was comparatively virtuous. Virtue was his making—*ecce homo*. " Freedom with Virtue takes her seat."

To every thinking person, the narrative of the ascent of man is one of the most fascinating of stories ; but it cannot be fully told until we have a more complete re-interpretation of the lives of plants and animals and of their mutual relations.

CHAPTER III

MALADIE ET SYMBIOSE

The great lines of medical progress, being indeed but of yesterday, are scarcely reaching beyond the anthropocentric orbit; they must be enlarged and blended with other lines of pathological research on a Copernican conception. . . . But this unity, if we are to grip principles at their beginnings, means not merely the beginnings of disease in man, but also in all animals, as they are alike for all; and not of animals only, but also of plants; in a word, of all life. . . . And yet in respect of a plan or system, comparative medicine is still without even a sketch, almost without a thought.—SIR CLIFFORD ALLBUTT, *Times*, 8/12/19.

NE peut-on pas espérer que l'étude de la Symbiose entre des organismes arrivés aux limites de la tolérance mutuelle donnerait des ressources nouvelles pour comprendre les lois de l'immunité ou de la maladie ?

This passage occurs in a brilliant and, according to *Nature*, "important" paper entitled *L'Evolution dans la Symbiose*, by Prof. Noël Bernard (*Annales des sciences naturelles*, 1909).

At first glance one might be led to suppose that the author of the passage had in mind something radically new concerning the problem of disease and of immunity. Such expectation, however, is not fulfilled, although the paper is suggestive in many ways.

Firstly, what kind of "tolerance" and of "immunity" is it that Prof. Bernard has in view? Certainly not a very substantial, but rather an attenuated form in either case. He thinks of a "tolerance" greatly inferior to that exhibited by advanced and cross-feeding symbiotic partners, of one in fact closely approximating "intolerance," *i.e.*, mutual depredation between organisms; whilst the "immunity" contemplated by him, is scant, unreliable and suspect—far removed from that engendered by genuine symbiotic relations.

Unfortunately, Prof. Bernard is committed to the narrow view which confines Symbiosis to physical attachment of the partners—a view baldly expressed in the *Encyclopædia Britannica*.

The *naïveté* of this view may be gleaned from the fact that the writer in that publication argues as though dependence of organism upon organism with regard to food constituted the

prejudicial feature of Parasitism, a view which would cause, as the writer himself realises, almost all organisms to be classed as parasites, seeing that they are in one way or another dependent upon one another. True, the writer at least grants that green plants, since they build up their food from the inorganic elements, from the air and the soil, "are furthest removed from the suspicion of dependence"; but it seems scarcely ever to have dawned upon that writer that we must clearly distinguish kinds and degrees of "dependence." On a reasonable, bio-economic view of the matter, dependence *per se* is not a fault at all; but only illegitimate, *i.e.*, non-reciprocal dependence imparts the taint of Parasitism. The article in the *Encyclopædia* shows clearly that it is the absence of sociological criteria which has engendered so much misconception and confusion of thought in Biology. It is merely a "counsel of despair" when the writer continues: "The necessary additional conceptions are two: the bodies of host and parasite must be in temporary or permanent physical contact other than the mere preying of the latter on the former; and the presence of the parasite must not be beneficial, and is usually detrimental to the host."

Failing a sociological, we have here a physical conception, which has the effect of quite unduly narrowing down the issue. Whilst "contact" is over-emphasised, partnership is underestimated, and the rider with regard to the casual injuriousness of parasites reads rather as an afterthought, as an accidental and not as what it is, namely, the most important matter. Such being the premises of "la biologie positive," we cannot wonder at the comparative sterility of Prof. Bernard's conclusions with regard to immunity and disease, which, so far from providing the object lesson that Symbiosis and disease are opposites, have carried him not much further than to surmise that the two may well be "*des phénomènes comparables*" (p. 159).

A paltry conjecture indeed!

Prof. Bernard is not, as might perhaps be imagined, putting forward a theory akin to that of Symbiogenesis. He merely contends that there occurs a gradually intensified series of mutual adaptations between certain classes of orchids and fungi—precarious adaptations because liable to violent fluctuations in point of mutual usefulness, of healthiness and permanence.

After all that has been said in the preceding pages, it is

scarcely conceivable that from so unreliable an example of natural reciprocity an adequate and comprehensive view of the rôle of Symbiosis could be derived.

When, in the normal course of agriculture, we tend our food-plants, we act (usefully and healthfully) as the symbiotic partners of those plants. We serve them, and they reciprocate by serving us in an equally wholesome manner. The various secretions and "swellings" of plants, which are of high nutritive and evolutionary value to us, are thus provided by the plants in accordance with the socio-physiological principle of compensation. Upon this fundamental principle, Symbiosis is primarily based—a fact which Prof. Bernard is throughout loth to recognise, misled as he is by the idea of the identity of Symbiosis with disease.

It so happened that the kind of Symbiosis which more specially concerned him, was one taking place in the ends of the earth, as it were—to be more exact, in the roots of orchids, inhabited, or "infested," as these frequently are, by various kinds of fungi. (*"Les Orchidées et leurs Champignons commensaux."*)

My intention in criticising the "mémoire," is not to minimise the merit of the French Botanist's admirable research, or to make any animadversion upon his excellent and painstaking work; it is rather to impress my contemporaries as profoundly as possible with the fundamental truth, often obscured, or implicitly traversed, by such papers, that sociological laws apply very aptly in Nature, and, further, that such application is well calculated to open a new horizon with regard to the perennial problems of Health and Disease.

The usual orthodox aversion to a sociological view obtrudes itself in the very definition of Symbiosis, as vouchsafed for us by Prof. Bernard. He says that "symbiose implique souvent la croyance à une association mutualistique entre des commensaux capables de s'entr'aider," which is certainly non-committal, particularly with regard to sociological implications. Instead of "partnership," Prof. Bernard has thus hit upon "Commensalism," which is neither fish, flesh nor fowl, although sufficiently "non-moral" to neutralise the yet unavoidable sociological suggestion of "entr'aide."

("Commensalism" is a term introduced by P. J. Van Beneden to cover a large number of cases in which animals have established themselves on each other, and live together on a good understanding and without injury.)

Apart from its failure duly to emphasise the essentially sociological character of Symbiosis, the definition, by limiting the range of the symbiotic relation to "Commensalism," rather detracts from Prof. Bernard's recurrent intuition that Symbiosis might yet be found to be one of the mightiest factors of evolution. But does it not almost appear preposterous to write a paper on the evolution in Symbiosis when only the progress of a dubious kind of Commensalism is implied, and when Symbiosis at best is to represent nothing more than a rather intimate kind of Commensalism? Truly, interpretation is to-day more important to science than research.

In the introduction to his paper, Prof. Bernard tells us that

Dans ce cas de symbiose comme dans la plupart des autres, on sait seulement d'une façon positive que l'association des champignons et des plantes adultes est intime et *habituelle*. . . . Il faut partir de là, et si l'on veut comprendre par quels moyens la symbiose subsiste ou découvrir les secrets de son apparente harmonie, le plus utile est de chercher ses origines et de retracer son histoire. Cette idée évolutionniste a dominé mes études ; elle me permettra d'établir des rapports suggestifs entre les faits examinés dans ce mémoire.

In the absence of a settled view concerning the real inwardness of the phenomenon and respecting the underlying economy of nature, Prof. Bernard thus proclaims "ce cas de symbiose," as typical of all other forms, which, however, is only very partially true. To set out with an undue apprehension of the phenomenon, to credit it with no more than "apparent" harmony, and to regard it as a mere historical accident, does not augur well for a comprehensive interpretation of evolution in Symbiosis. The start should have been from the proposition that we have in Symbiosis a socio-physiological phenomenon, a partnership in fact, presenting all stages of harmony, from one which is more or less apparent and unstable to one which is very real and permanent.

How greatly Prof. Bernard's otherwise excellent work is marred by the lack of such orientation, may be gleaned from his remarks concerning "Les Origines de la Symbiose." This is what he says :

En réalité, les rares Orchidées qui atteignent l'état adulte ont été sélectionnées par les champignons dans des conditions minutieusement précises. Pour les embryons même, à qui les hasards de la dissémination des graines ont permis de rencontrer des Rhizoctones, la mort prématurée est la règle et la vie en symbiose est une exception. L'harmonie des

associations d'Orchidées et de Rhizoctones n'est pas, à beaucoup près, une loi universelle. Il n'est pas moins admirable que des milliers d'espèces de plantes, sujettes aux atteintes de champignons depuis l'origine de leur famille, présentent encore des individus capables de résister à ces hôtes tout en vivant avec eux dans un état d'intimité extrême, et il reste à savoir comment cet état de symbiose a pu s'établir et a évolué chez les ancêtres des Orchidées actuelles. Cela ne peut être qu'un sujet de *réflexions théoriques*, mais ces réflexions sont utiles à faire et susceptibles de quelque précision. (*Italics mine.*)

(Rhizoctonia are the fungi "infecting" the orchids in Prof. Bernard's experiments.)

As regards the evidence that the orchids are "selected" by the fungi, to say the least, it is slender and even contradictory. On our socio-physiological view, it follows quite logically that in order that there shall prevail really harmonious relations between orchid and fungus, the conditions must be somewhat specific—marking the degree of mutual aid and mutual forbearance. And we should not even stop to think that any and every couple of orchid and Rhizoctonia are fit for a life of partnership. Above all we expect to find obedience to some basal law of Concord by both partners in an association of real merit. In view of the universal frailty of life—so apt to set at nought the fundamental biological concord, as in matters of food, for instance—we should expect to meet with numbers of fungi which, in Prof. Bernard's words, are "*imparfaitement préparés à la vie commune*," and we should expect, moreover, to find that frequently, in a case of this sort, the compatibilities are of a kind to favour a parasitic rather than a symbiotic relation. The chief truth in these matters, which again I wish particularly to enforce, is that which is totally omitted, if not implicitly denied by the French Botanist, namely, that the path of Symbiosis, although not necessarily the path of least resistance, is yet the path of health—the path most sanctioned by Nature. Prof. Bernard is barred from such recognition by the fundamental error that "immunity" and not "partnership" constitutes the alternative of the state of mutual plunder leading up to disease.

Like Darwin, he dwells upon the fact of the comparatively poor distribution of the orchids in nature, "*bien qu'elles prodiguent leurs semences, chaque plante pouvant produire par milliers ou par millions des graines impalpables.*"

This sparse distribution of orchids is as puzzling to him as is the frequency of "harmony" between orchid and fungus, which

"harmony," or "intimacy," or "immunity," is yet, as he thinks, not in accordance with any "loi universelle." Why, if they are capable of achieving "harmony" and "immunity," and even of apparently excelling in seed production, could not the orchids have been more liberally distributed in Nature? Is it that Nature favours distribution of species arbitrarily and contradictorily? Does she really sanction harmony and immunity only to saddle the respective species with the dire necessity of a wasteful seed production? But Nature does not act thus irregularly and contrarily; and whenever such puzzling cases arise, we are not far wrong in assuming that abuse has been mistaken for use, as a result of which the respective operations of Nature have been seen out of focus.

Darwin at least suggested as an explanation why the orchids are but sparsely distributed in Nature, that perhaps they are not useful enough to the (symbiotic) insects—a very valid reason, in my opinion. But the French Botanist ignores bio-economic criteria. He bids us instead follow him, somewhat tangentially, into the labyrinth of past history. But we may be sure that whatever has been the past history of the orchids, they have at all times been under the cardinal necessity of obeying the law of give and take, and we may feel confident that the species prospered in any real sense only *au fur et à mesure* as they learnt progressively to comply with this law. Whatever degree or kind of "immunity" they acquired as a result of their dealings with the fungi, if such acquisition ran counter to real biological usefulness, this was certain to make against a successful distribution of the species. And this is a very important lesson to be gleaned from their case.

It may be well at this stage of our analysis, to pause for a moment and consider the position of fungi and of orchids regarded as bio-economic agents. Apart from such considerations, a right understanding of their inter-relations is well-nigh impossible. The fungi, as a class, as is well known, feed upon, and break down, decaying organic matter. We must interpret this as meaning that they have for the most part become confirmed in in-feeding habits. And the habit has grown to such an extent as to render them destitute of chlorophyll, and, hence, wanting in the matter of the most essential vegetable industry, the glory of the green plant, namely, the manufacture of carbo-hydrates. Incidentally, and for the same reason, they have become relegated

to a *cul-de-sac* of evolution. Most fungi resemble the colourless cells of higher plants in their nutrition. Like them, they require water, small but indispensable quantities of salts of Potassium, Magnesium, Sulphur, and Phosphorus, and supplies of carbonaceous and nitrogenous matters in varying stages of complexity in the different cases. Like them also, they respire oxygen, and are independent of light; and the several powers of growth, secretion and general metabolism, irritability and response to external factors, show similar specific variations in both cases. "Free-lances," or "Free-booters," though they be, the fungi are thus by their needs dependent upon green plants—dead or alive. And there is clearly some opportunity for the fungi, by being in turn useful to the green plants,—reverting to the symbiotic usefulness of the colourless cells in an ordinary higher plant—to rehabilitate themselves to some extent as useful bio-economic agents, and, though not, as autonomous beings, re-exalted in the evolutionary scale (which would be contrary to the "law of loss" or "irreversibility,") yet strengthened in their general powers for good, and even elevated through union, as is clearly instanced by the case of the lichen. *De toute taille bon chien*. Large numbers of fungi, of course, are well known to gain their living exclusively by parasitic short-cuts. If others occasionally submit to Symbiosis, they are not yet quite degenerate and do so under a special compulsion, making a virtue of necessity, e.g., when other means of gaining a livelihood are wanting, or when they are occasionally made to yield to the pressure of symbiotic momenta in the shape of prepotent "good influences" wielded by higher plants. The ancestors of the fungi, be it remembered, were green plants, and, hence, were undoubtedly possessed of some symbiotic disposition. We may take it that even in degeneration the symbiotic sense is frequently not entirely defunct, but only in abeyance and capable of some reawakening on appropriate occasions; and I believe that this applies in the case of both fungi and orchids. Even in highly saprophytic orchids there occurs not infrequently a reappearance of green cells, and we may confidently believe that similarly there exist residues—rudiments—of an erstwhile more developed symbiotic sense even amongst the lower classes of plants, such as the fungi, some of which may be but little inclined to be saprophytic.

In case of Symbiosis between orchids and fungi, the rôle of

the fungus appears to be to supply materials in forms which the usual root-hairs of the orchid are incapable of providing; in return the latter supports the fungus at slight expense from its abundant stores of reserve materials. The writer on *Fungi* in the *Encyclopædia Britannica* declares such Symbiosis to be a "dualism" where, as in the case of the lichen, "the one constituent (alga) supplies carbohydrates and the other (fungus) ensures the supply of mineral matters, shade and moisture," and, evidently, some fungi at least draw as cross-feeders upon mineral matter. Although this writer is evidently thinking of a good case of Symbiosis, he is yet prejudiced by the usual uncertainties with regard to the determining socio-physiological factors constituting Symbiosis. He does not know how to discriminate, in other words, between good and comparatively bad (trivial) kinds of Symbiosis. But if we fail to realise that there are gradations in "partnerships," and if we mix up promiscuously good with bad cases, we are apt to arrive at an inadequate appreciation of Symbiosis, which is at the same time a slander upon Nature. How then are we to assess the value of orchid-cum-fungus Symbiosis?

If we had none but orthodox criteria to go upon, we should no doubt say that such a plant-cum-plant Symbiosis is of the same significance as an animal-cum-plant Symbiosis. In the latter Symbiosis, we might say, the animal merely takes the place of the colourless cells referred to above, and the fungi do the same *vis-à-vis* to the orchids. Such a view of the matter would be encouraged by the common fallacy that "symbionts," be they animals or plants, only wish to "devour" each other without any provocation. The fungus, so the argument would run, is only another typical Cain, or at best a would-be Cain, such as is the animal. But we cannot any longer rest content with such crude and disingenuous views. We must seek to gain a wider perspective. A partnership, however expedient for local purposes, if it run counter to the great economic scheme of Nature, *e.g.*, in matters of respiration, detracts *pro tanto* from another, more fundamental and essential kind of partnership, namely, that which is in harmony with the great economy of Nature: the ordinary animal-cum-plant Symbiosis. I would therefore distinguish between a "Norm-Symbiosis"—all-essential and widely and variously useful—and a mere "Luxury-Symbiosis"—representing by comparison a "lazy compliance with low

conditions " and even antagonistic to the former inasmuch as the bad is the enemy of the good. Orchid-cum-fungus Symbiosis, in my opinion, is a "Luxury Symbiosis," detracting from the value of orchid-cum-insect Symbiosis and leaving the organism which has most to lose through inferior association, namely the orchid, the poorer in the end. Often enough the moribund condition of the orchid is marked by its sickly appearance, whilst its general "illth" may also be gleaned from its sparse distribution.

Like the fungus, the orchid, too, has an interest in dead or decaying organic matter, being little given to tilth in pioneer fashion. And roots which are not properly exercised, like teeth with too much soft and sloppy food, decay. The orchid, being thus situated, finds "congenial" helpers in the fungi which, provided certain conditions of mutual exchange are fulfilled, are able to supplement the needs of the orchid in some important ways.

What Prof. Bernard claims to have done is this :

J'ai cherché comment l'état de symbiose se modifie quand on passe d'Orchidées simples et primitives à d'autres qui atteignent un plus haut degré de complexité. J'estime avoir ainsi apprécié les étapes successives de l'adaptation des Orchidées à leurs hôtes avec autant de certitude qu'on en puisse espérer en semblable matière.

And he has found that :

Au degré le plus inférieur, chez de rares Orchidées comme *Bletilla hyacinthina*, la symbiose ne s'établit pas nécessairement dès le début de la vie ; les plantules peuvent avoir un développement autonome plus ou moins prolongé. L'association une fois réalisée reste d'ailleurs intermittente : chaque année des racines se développent et s'infestent, pendant que poussent les tiges aériennes fugaces ; puis, les racines meurent, comme les tiges mêmes, et la plante reste pendant plusieurs mois réduite à un rhizome indemne de champignons. Dans ce cas même l'infestation des racines chez les plantes adultes est la règle et l'on peut parler de symbiose. Mais l'état d'un *Bletilla* est en réalité bien proche de celui d'une plante sujette à une maladie cryptogamique bénigne, capable de récidiver.

All of which, however, fails to enlighten us about what is most worth knowing, namely, concerning the determining factor of partnership or "concord," on the one, and of "maladie," or "discord," on the other hand. Clearly "maladie bénigne," will not do ; neither can we countenance "proximity" of "maladie bénigne," which is far too ambiguous, for a little more of "bénigne" may usher in perfect health almost before we know it. It is already perplexing enough to find such terms as "adaptation" and "host" indiscriminately bandied about in

these connections. If we are dealing merely with "adaptation," then there seems little justification for the bringing in of Pathology at all, and if, on the other hand, we are dealing with "hosts" then we should confine ourselves to disease without bringing in "adaptations." Much confusion would be relieved, and great might be our gains generally, could we but be more enlightened with regard to "predisposition." Under what conditions of "soil" is a micro-organism tempted to become morbidly, or, in the alternative, healthily, "part of us"? That again is the question. Here modern Pathology cannot assist us, for it does not concern itself with such fundamental causes as the biological merits or demerits of the organism. It is waiting for some synthesis from General Biology, which is itself on the look out for new inspirations with regard to the subject of inter-relations. As Prof. Patrick Geddes has it in a preface to a book by Massart & Vandervelde, on *Parasitism, Organic and Social* :

May we not, therefore, hope some day to see an antithetical title to the present one—Symbiosis, Social and Organic? Neither economist, nor naturalist is ready to write such a book.

Meanwhile, we remain uncertain with regard to the most fundamental and most important matters, and the orthodox Biologist carefully avoids the subject of biological merits or demerits. Frequently, in the absence of a court of appeal as potent as that afforded by Bio-Economics, he disowns "values" altogether. But how can Pathology prosper without values, and in its turn inspire Biology?

In its primitive form, Prof. Bernard insists that "la symbiose est manifestement à la frontière de la maladie," whilst "sous ses formes le plus parfaites, elle reste un état exceptionnellement réalisé."

Apart from a few slightly exceptional cases, then, we are to believe that Symbiosis is a state bordering on disease. If we come to examine the "exceptions" where, as alleged, Symbiosis is realised (un haut degré de perfection), we find figuring prominently the case of the notorious *Neottia Nidus-avis*—an in-feeding, in-breeding, almost totally "saprophytic" orchid. This we are to recognise as the culmination of Symbiosis :

Sous sa forme la plus parfaite, dont l'étude du *Neottia Nidus-avis* fournit un des meilleurs exemples, la symbiose devient continue. Non seulement les graines ne germent pas sans le concours d'un champignon, mais encore ce champignon ne cesse pas de se propager dans la plante

qu'il a dès l'abord envahie, jusqu'au moment où elle meurt. Quand on arrive à ce cas ultime d'une plante incapable de vivre à aucun moment sans son hôte, la notion de l'individualité perd son sens habituel. *L'association du Rhizoctone et de l'Orchidée mérite plus que l'Orchidée même d'être considérée comme un individu.* Un *Neottia Nidus-avis* n'est pas plus comparable à une plante autonome qu'un Lichen ne l'est à une Algue.

How little has it thus been realised that successes such as that of the Bird's-nest Orchis are more apparent than real, that they are attended by morbidity which, though not acute, is disease nevertheless ! How little has it been seen that, evolution being essentially a socio-physiological process, the fact of " back-sliding " in bio-economic integrity entails progressive diminution of support and of resistance, which is equivalent to a lingering and long protracted disease of the species. True, for practical purposes, the Rhizoctonia has become entirely part of *Neottia*, which is no more " autonomous " without its fungus than the lichen is without its alga. But if we compare the case of *Neottia* with a typical Norm-Symbiosis, then we shall find that there is here a vast difference. For the *Neottia*-partnership is totally deficient in that healthiness which marks the Norm-Symbiosis and even Lichen-Symbiosis. *Neottia*-partnership only yields a saprophytic *ensemble*, characterised in season by a cluster of sickly looking flowers on a yellowish or brown stem. And inasmuch as there is such retrogression, there is disease, although in the sense of Acromegaly and not in the sense imagined by Prof. Bernard. The disease is in fact constituted by the correlated retrogression in, or the divorce from, a higher form of Symbiosis ; not that Symbiosis *per se* constitutes disease. Mere " autonomy " counts for little when such wider issues are concerned. " Autonomy " may be, and very usually is, a better way than a " liaison " involving nothing more than Luxury-Symbiosis. The " pre-occupation " of the orchid with the fungus has robbed it of much superior intercourse with the insect. Hence the loss of " autonomy " here means chiefly loss of " Norm-Symbiosis." Such loss, caused by a life of undue self-limitation and undue self-sufficiency, contrary to Prof. Bernard's opinion, does not constitute the essence of true Symbiosis.

When Prof. Bernard tells us that, as the result of his investigations, it could scarcely be doubted " qu'il y ait eu chez les Orchidées une évolution progressive, depuis la maladie intermittente, jusqu'à la symbiose continue," this shows again how

greatly he has misunderstood the meaning of Symbiosis, which has led him to confound healthy with moribund associations. Though in *Neottia Nidus-avis*, orchid and fungus have come closer together, this is by no means proof of progress in a real sense. The closer union is merely connected with the orchid's "progress" in saprophytism, which antagonised an erstwhile healthier interaction though with more limited confinement of the fungus' sphere of application. True the propagation of the fungus takes place within the orchid ; but there is no indication that such intimacy takes any other but a selfish course, that the fungus takes upon itself say any share of the " partner's " labours of reproduction, as it does in the case of the more benignly compounded lichen. *Neottia Nidus-avis*, indeed, illustrates the downward terminus of Symbiosis, with the " shadow "—the physical attachment—well to the fore, but with the " substance "—the mutual elevation—in the background, if not altogether wanting. It is possible, however, that in the past, and under special conditions, the fungi have been more useful to the orchids than frequently they are now, so that the past association of these plants may have been fraught with considerable consequences, though not exactly those visualised by Prof. Bernard. We may recall here the case of *Heterodera*, the Nematode which is useful to the plants in the desert, though highly injurious on meeting them in cultivation. Much, therefore, depends upon time and space with their different compatibilities.

Be this as it may, inasmuch as the orchids tend to luxuriate rather than to " spin," this, in my opinion, inevitably makes for loss of vitality with compatibilities towards the pathological order. The metabolism of these plants, as the result of increasing in-feeding, must needs proceed pathologically, with the result that scavengers are " chemotropically " attracted. Some such scavengers, so long as they are not yet too immoderate and still " préparés à la vie commune," may, for a time, and precariously, be taken into a kind of co-partnership by the higher plant. The fungus becomes a hewer of wood—breaking down cellulose—and a drawer of water, employed much in the same way as the plant employs elemental agencies for its various purposes, save for the difference in sociological implications. But just as an anemophilous plant, relying upon low associations and with a consequent wasteful production of pollen, is of inferior status to an entomophilous one, so a plant of low organic associations, other things

equal, is inferior in status to one in Norm-Symbiosis. The "anemophilous" plants, as we have seen, are even apt to be —miscreant-like—a source of danger to the aristocracy of life. We may say that plants which are partly "déracinées" through saprophytism and partly "blasées" through Luxury-Symbiosis, are apt to be derogatory to the community of strenuous life, so as to require to be penalised accordingly. And many orchids have arrived at the zone of danger, whilst lack of distribution in others is a symptom of biological retribution for wasteful ways. It may not be out of place here to give an account, though rather grotesque, from Prof. Bernard's own pen, of the status of the orchids, to the study of which he had devoted his life. The passage occurs in a letter published by Prof. J. Costantin in a preface that he has written to Noël Bernard's *L'Evolution des Plantes*.

Les Orchidées des forêts tropicales n'ont pas adopté les mœurs des autres végétaux ; elles vivent à l'écart, loin du sol, retenues aux branches élevées des arbres par les solides griffes que forment leurs racines. Leur vie est précaire, menacée par les ouragans ou la sécheresse, rendue difficile par le commensalisme de microbes qu'on a cru bienfaisants seulement parce qu'ils sont tolérés. Elles auraient sans doute parmi les autres plantes, si les plantes avaient le préjugé des conventions communes, une mauvaise réputation d'orgueil et de sauvagerie ; l'on citerait comme des tares qu'elles dissimulent les difficultés qu'elles rencontrent et les luttes qu'elles soutiennent au cours d'un pénible développement. Mais il me plaît de croire qu'elles n'écoutent point les propos des plantes qui rampent à terre ; elles ont eu l'audace, au mépris des difficultés, de quitter le sol qui leur assurait une part de banale nourriture pour rechercher la lumière sur les cimes de la forêt. Les fleurs qu'elles déploient en plein soleil, étranges par leur symétrie et leur structure, complexes mais magnifiques, vivent dans un air plus pur où elles n'ont plus que la visite des insectes vivant de nectar.

The passage certainly is evidence that Prof. Bernard strove at times to rise above the limitations of watertight compartments of science. He is really attempting something of the sort, though, in my opinion, with ill-success, when he likens fungal "aptitude physiologique à la symbiose" to "la virulence des microorganismes pathogènes." Here his bias in favour of pathological interpretation misleads him into believing that, since fungi may occasionally lose their symbiotic capacity "gradually," whilst others may gain virulence also "gradually," and since in either event considerable reactions come about, the phenomena of Symbiosis and disease are not far apart from one another in significance. But

this is a great error and is, in fact, confounding two opposite principles, namely, that of obtaining food by honest labour, on the one hand, and that of obtaining it without, on the other—though still under association ; for it is, of course, not so much association *per se* as the value in organic civilisation of the association that counts. Had the French Botanist but fully realised the real possibilities of the “ aptitude physiologique à la symbiose,” as illustrated by the highest forms of Norm-Symbiosis, how very different would have been his outlook ! Even his discovery of the occasional use made by higher plants of a kind of Phagocytosis, and his reference to the “ humoral ” capacities of organisms, fail to convince us that Symbiosis is cognate to disease. These factors of defence merely come under the head of general resistance, in which an organism is the richer the more it contributes to the sum of organic well-being. The power of Phagocytosis itself I consider to be the outcome of (internal) Symbiosis. I have already stressed the fact that many low and parasitic species of animals are deficient in wandering phagocytes—the lack of useful activity on the part of the species involving lack of symbiotic support. In the symbiotic relation between orchid and fungus, Prof. Bernard sees

un trait de mœurs très ancien, antérieur même, selon toute apparence, à l'époque reculée où sont apparus les premiers représentants de cette grande famille de plantes.

Instead of “ trait de mœurs,” I would here speak of symbiotic sense as a conception more in accordance with the facts of co-evolution between animals and plants, including psychological correlations. Such symbiotic sense is capable of many special applications, modifications and also of reversals. We may well grant the remote origin of the inter-relation between orchids and fungi ; but, as I have said, we must weigh the possibility of a onetime totally different value in the relation. Evidently, some fungi have preserved the symbiotic sense better than others, for we are told that :

D'autre part, la perte du pouvoir de faire germer les graines chez les Rhizoctones soumis à la vie autonome tend à montrer qu'il existe dans la nature, pour chaque espèce de ces champignons, deux séries de races distinctes. . . . L'une de ces séries comprend les Rhizoctones commensaux qui sont passés sans cesse d'une Orchidée à une autre, sans intervalles de vie autonome assez longs pour que l'activité nécessaire à l'établissement de chaque association nouvelle ait été perdue. L'autre

série, qui a pu se constituer et qui doit s'enrichir aux dépens de la première, comprend les Rhizoctones saprophytes, ayant perdu toute activité, incapables de contracter la vie commune avec des graines.

This rather points to saprophytism, *i.e.*, the exploitative and in-feeding method as the universal cause of loss of symbiotic sense and of symbiotic capacity ; and it supports my contention of the suspect character of Neottia-Symbiosis. The lesson seems to be that the more a plant becomes converted to pure in-feeding, the less is its inclination to Symbiosis. Some fungi, no doubt, are "mixed" feeders, drawing partly on soil and partly on organic matter, according to circumstances. The more they are made to support themselves mainly on (earned) cross-food, the more they are fit for work and Symbiosis in the best sense of the word. [Prof. Bernard's "well-disciplined" Rhizoctonia showed again and again their propensity for what I call "in-feeding" by digesting cellulose.]

Corroboration of my nutritional view may be seen in the fact discovered by Prof. Bernard, that the symbiotic Rhizoctonia lose their activity in greenhouses, where, only too frequently, they are provided with temptations in the shape of rich (organic) food, which, on my interpretation, causes them to become indolent and merely self-regarding in-feeders ("holo-saprophytes"). Having thus become too lazy for the duties of co-partnership, they degenerate into "autonomy," *i.e.*, into inefficiency, social and organic. To expect symbiotic labours, symbiotic forbearance, or symbiotic disposition of a pronounced order from a pampered holo-saprophyte, is indeed "demander de la laine à un âne."

With regard to the "modes de développement," of orchids, the French Botanist concludes that the formation of a "protocorm" must be regarded as a character acquired as a result of developments inherent in a life of Symbiosis, *i.e.*, in association with fungi :

En fait, chez les Orchidées à rhizome, le protocorme est le début de cet organe et, chez les Orchidées à bulbes, le protocorme tubérisé mérite d'être considéré comme le premier des bulbes produits par la plante.

This protocorm is largely "infected" with fungi :

L'apparition du protocorme marque pour ainsi dire la plus récente étape de l'évolution accomplie par l'influence des Rhizoctones, mais assurément des étapes antérieures nous échappent, car même les *Bletilla* vivent déjà avec leurs champignons dans un état de symbiose bien caractérisé.

It remains to be seen, therefore, to what precise causes were

due the "transformations initiales" of the ancestors of the orchids. Meanwhile Prof. Bernard's hypothesis is that, since it is Symbiosis, which "dans ses progrès ultimes," *i.e.*, in the only form in which Symbiosis is known to him, causes the increasingly precocious formations of bulbs and rhizoms, one may conclude that the inception of these organs is also due to a primordially established Symbiosis. And this may be true, although it is to be doubted that it was Symbiosis of the kind envisaged by Prof. Bernard that performed the feat.

We are indeed soon reminded by Prof. Bernard's own further reflections that with a little supplementary argument there is good reason for taking a view of the origin of Symbiosis different from the one he favours. This is what we are told under the head of "Diverses conditions équivalentes à la symbiose":

L'établissement d'un mode spécial de croissance "par épaissement" a dû être la réaction initiale des plantules chez les espèces les moins adaptées à la symbiose. Mais ce mode de croissance même s'observe communément au début de la formation de tubercules chez des plantes diverses et aussi dans bien d'autres cas; il est, en somme, d'une nature banale au même titre que d'autres phénomènes du développement. L'infestation par des champignons apparaît comme une condition très particulière, mais les réactions qu'elle entraîne, envisagées en elles-mêmes, n'ont rien de spécial au cas des Orchidées.

Granted that there has been a "thickening" as an initial reaction of the seedlings when they first became adapted to useful interaction with fungi; granted further, and even with special emphasis, that we are here dealing with a fairly universal phenomenon—closely approximating non-pathological "Norm-Symbiosis"—how are we to interpret the evolutionary significance of the phenomenon?

We shall not regard it with the French professor as a trivial matter, but insist that it is due to the fact that services have been rendered to the plant by some partner, as a result of which services, and in accordance with the sociological principle of compensation, the plant reciprocates by storing up reserve materials for "export"—for the purposes of Symbiosis in the wider meaning of the term. There is nothing "très particulière" in orchid-cum-fungus Symbiosis, inasmuch as by its reactions it is merely seen to illustrate the operation of compensation. On the other hand, this Symbiosis is, indeed, "particulière" inasmuch as it is apt to impair the progress of normal exchange relations in the world of life, which relations, contrary to Prof. Bernard's belief in the

matter, tend in the direction of non-attachment of partners. Prof. Bernard's Symbiosis must be considered as exceptional, in other words, because it is a form tending to a reversal of true Symbiosis. More especially is this the case when it is "Symbiose continue," which represents, I believe, merely the success of partnership in Saprophytism, which in reality unfits both, orchid and fungus, for the demands of genuine Symbiosis, and is, hence, a factor prejudicial to cross-fertilisation by insect agency and detrimental to higher developments generally. Once a plant has contracted the in-feeding diathesis, such diathesis is apt to grow inordinately. Either, therefore, the orchid, seeking to increase its indulgences, makes excessive demands upon the fungus, often destroying it altogether, or, the fungus becoming immoderate in its turn, sets up active disease in the plant. In either event the conditions due to Symbiosis proper are unfulfilled.

In a previous chapter I have shown that the usual method of Domestication, as too one-sided exploitation, is equivalent to a divorce of the exploited organism from its true symbiotic bond in Nature, from Norm-Symbiosis in fact, and that this results in disease, so that it is futile to think that to such or similar methods pride of place could be accorded amongst factors of evolution. And so it is here where similar substitutions are taking place. Though the abuse of an oft-times useful relation is thus of frequent occurrence, even in Nature, it is yet very essential that we do not mistake such abuse for the use. The progress in one-sided exploitation, though still an "adaptation," no more represents the norm of evolution than the production of alkaloid poisons (in defence against such exploitation) represents the norm of vegetable manufacture.

Seeing that Prof. Bernard fails to make such distinctions, I cannot attach the same importance as he does to his discoveries with regard to "equivalents" of Symbiosis. They amount to this: In the absence of fungi, the orchids may be made to germinate and to develop "autonomy" if certain organic solutions are supplied in high concentration, which, however, may only mean an equivalence of service rather than "physical" or "chemical" equivalence. For man here takes the place of the fungus, and he supplies that which under ordinary "infected" circumstances the orchid receives through the accustomed stimulations of its fungal partner. Service is the most valid equivalence in Symbiosis.

We are told :

Quand on consulte les statistiques données par Schlicht, Janse, Stahl, Galland, ou d'autres, sur les cas de symbiose chez les végétaux supérieurs, les meilleures règles générales qu'on arrive à dégager sont les suivantes : *la presque totalité des plantes herbacées vivaces et le plus grand nombre des plantes arborescentes hébergent des champignons* ; les plantes annuelles au contraire sont régulièrement indemnes.

I should consider it, on many grounds, far from likely that in most of these cases the fungi have played the same part as in the orchids. In some cases their rôle may have been merely to supply water ; in others they may have gained ingress only temporarily and without being permitted to effect any noteworthy change at all.

Prof. Bernard throws out the hint that all evolutionary progress may be based upon what one might call "nurtural" (sociological) contrivances, as the following passage indicates :

Peut-on affirmer que des caractères constants dans les conditions naturelles de la vie, apparemment capables de servir à la définition des espèces, ne sont pas en réalité des *caractères adaptatifs persistant grâce au maintien de conditions de vie constantes* bien qu'encore inconnues ou trop mal définies, comme persistent les caractères propres des betteraves sucrières grâce aux soins constants et bien connus du cultivateur ?

In other words, the organism has become what it is, because of what it has done or left undone in the course of its evolution, and the conditions of its development "encore inconnues ou trop mal définies," are precisely the sociological conditions for which it was itself in large measure responsible. Instead of "cultivateur" and "soins constants et bien connus," read "symbiotic partner," "symbiotic endeavour," and "symbiotic awareness," and it is plain that the study of Symbiosis has brought Prof. Bernard "malgré soi," as it were, within measurable distance of the recognition for which I contend, namely, that evolution is pre-eminently a socio-physiological process.

According to Prof. Bernard's discovery, the fungi which live in Symbiosis with the orchids, are marked by a special mode of growth when living in the roots or in the tissues of seedlings : ils envahissent les cellules de proche en proche en formant dans chacune, avant de gagner la voisine, un peloton de filaments contournés, ramifiés et enchevêtrés d'une façon fort complexe.

That is to say that the hyphæ of the fungus, under such conditions, form very characteristic clusters. I would interpret this as indicating that the effect of Symbiosis upon the fungus

is to encourage growth rather than mere Reproduction ; and we have here, I believe, the usual antithesis, on which I have throughout insisted, between Symbiosis and redundant Reproduction, *i.e.*, between widely useful and, on the other hand, merely self-regarding development. I concluded that *Neottia*, notwithstanding the appearance of "symbiose continue," represents in reality a reversal of Symbiosis, and this chiefly on the ground of the pronounced saprophytism of the orchid. If it present a case where the usual restraint associated with Symbiosis is less marked, inasmuch as the fungus easily propagates itself within the plant, we may say that *Neottia* has lost its symbiotic hold on the fungus in proportion as it has receded in general utility. The easy propagation of the fungus within the orchid, in other words, must be read as signifying the progress, not of genuine, but of reversal-Symbiosis, which backward progression is tantamount to a loss of restraint and of restraining power. The phenomenon is on a par with the usual loss of integrity in an organism on a conversion from cross- to in-feeding, *i.e.*, on any disturbance of previous important symbiotic relations. We have seen that under such or similar circumstances a plant may "lose its head" ; and we may similarly regard it as a loss of integrity and of discernment due to the habit of in-feeding when we find that certain insectivorous birds, for instance, are "stupid" enough to nurse the cuckoo's offspring. "Jamais," Prof. Bernard goes on to say, "le champignon ne forme de spores ni d'organes reproducteurs d'aucune sorte dans les tissus des plantes en bon état."

Whether the restraint be due to phagocytosis, or some other similar defensive factor, the chief emphasis is due to the fact that the symbiotic relation is the antidote of excessive and pathological multiplication.

Prof. Bernard has found that :

Les jeunes pelotons extraits de cellules où ils viennent de se former peuvent se développer en donnant du mycélium libre quand on les sème sur un milieu nutritif approprié.

With regard to the remarkable formation of clusters by the fungal hyphæ, we are further told :

En somme, cette propriété du pelotonnement est assez banale ; les champignons qui m'occupent ici ne sont pas les seuls à la présenter ; ils la possédaient peut-être avant de vivre avec les Orchidées ; elle a dû, en tout cas, être très favorable pour l'adaptation à la symbiose dont le

maintien paraît lié à l'existence de ce singulier mode de végétation des champignons endophytes.

Quite probably the respective fungi have preserved from the happy days of ancestral Norm-Symbiosis, or at least of neighbourly good relations with the ancestors of the orchids, sufficient symbiotic apparatus and sufficient symbiotic sense still to incline them to some integrity of growth under appropriate conditions of mutuality. The fact that glycogen, *i.e.*, a reserve product of metabolism, useful for work, is sometimes found in these clusters, inclines me to the belief that the cluster formation has to do with a gradual and specific exchange of substances between partners. Such exchange may be facilitated by an extension of surface, as by means of clusters, and this brings into operation the force of surface-tension—a force in virtue of which the physical properties of many substances may be altered. In effecting such changes and lending themselves to the corresponding exchanges, the fungi may well be thought of as rendering themselves useful to the higher plants much in the same way as the Agriculturist, by providing manure and general conditions, assists (symbiotically) our food plants. Nor, as in the above case, need the respective processes depend upon physical attachment or upon penetration of the orchid by the fungi.

To what an extent the orchids have become “*déracinées*” in the course of their reversal of Norm-Symbiosis, may be gleaned, though probably but imperfectly, from Prof. Bernard's description of *Bletilla hyacinthina*, a very low exotic orchid, in which there are nevertheless united, as he thinks :

un ensemble de caractères communs à toutes les Orchidées primitives en général, tels que l'habitat terrestre, le mode de végétation sympodial, la préfoliation convolutive, la position terminale des inflorescences, l'indépendance des masses polliniques par rapport au rostellum.

In the state of rest, such as one may behold in the plant in December, *Bletilla*, we are told, is

réduite à un rhizome articulé, souvent ramifié, toujours vert et superficiel. Chaque article du rhizome est constitué par un tubercule discoïde montrant les cicatrices circulaires de feuilles tombées et relié à l'article suivant par une courte digitation horizontale ; là où le rhizome se ramifie, un même article est relié par deux digitations à deux tubercules voisins. A l'époque dont je parle, ce rhizome ne porte que des débris de racines plus ou moins désorganisées et aucune racine vivante. (*Italics mine.*)

Yet (since the reversal of Norm-Symbiosis in this case has probably not proceeded too far), what a startling amount of

symbiotic forbearance is exhibited by *Bletilla* and its fungal partners :

La plante, au cours de sa période de végétation active, différencie ses principaux organes sans avoir à subir l'action des champignons. Elle est soumise à cette action seulement à partir du début de la seconde période, pendant un temps difficile à limiter exactement mais qui ne doit pas dépasser six mois. C'est pendant ce temps qu'elle forme son rhizome et qu'elle mûrit ses fruits.

Here, then, the "infection" sets in only at "harvest-time." The fungi, in their turn, are "assujettis à un régime analogue," and this so much so as to find themselves "empêchés d'accroître d'une façon continue leur pouvoir d'action sur leur hôte."

Prof. Bernard, by the way, seems to attach too little importance to the fact that the orchids belong to the Monocotyledons, the class of flowering plants in which the embryo of the seed has only a single cotyledon or seed-leaf, and which class seems to be marked by a "congenital" weakness as regards root-development. Thus, though in their earlier stages Palms develop a *radicle* or tap-root, no British representatives of the class do so ; nor, with the one exception of the Butcher's Broom, do they form woody stems. Monocotyledons have generally bunches of fibrous roots ; their stems are often bulbs or corms, and are not commonly much branched. But if the Monocotyledons are backward in the most important matter of root-development, they are certain to be correspondingly backward in the matters of "capitalisation" and of "export," and generally thus to present a comparatively inferior "trade-balance." They cannot vie with the more strenuous Dicotyledons for the most complete fare, and for the choicest biological services. Though they be but relatively backward, this is enough to involve liability to disease in view of the eternal antagonism between the good and the (relatively) bad, and inasmuch as health and status are to a large extent determined by socio-physiological factors. We must be on our guard, therefore, lest we make any and every monocotyledonous development the measure of normal and primary development amongst plants generally. This is how Prof. Bernard, on p. 43, refers to the class-character of the orchids :

Chez les Monocotyledones en général, les graines mûres ont un albumen et un embryon normalement différencié ; il devait en être ainsi chez les ancêtres des Orchidées. Mais chez la plupart des représentants actuels de cette famille, l'albumen disparaît de très bonne heure dans la jeune graine, ou ne s'y forme pas du tout ; l'embryon reste indifférencié, sans

cotylédon ni radicule ; souvent il porte encore un suspenseur à sa maturité. Le tégument de la graine est mince, réticulé, et d'ordinaire transparent.

To judge even from the case of *Bletilla*, as depicted by Prof. Bernard, the orchids at one time provided better for their progeny ; they were, in my interpretation, better organisers, better workers, better capitalists, and *pari passu* offered more resistance to fungal penetration. They provided more albumen, more starch, more sugar, more nectar, and, quite probably, all of it in higher quality than now. The value of such substances, as we have seen, largely depends upon their molecular constitution, and this, in turn upon origin and nurture, and, hence, also upon association and interaction. *Bletilla*, as a comparatively normal orchid, does not yet present "les formes juvéniles si particulières des Orchidées à protocorme," and it appears that "les caractères du premier développement chez *Bletilla hyacinthina* sont des vestiges, rarement conservés, d'un état ancestral." And these ancestral characters, we may feel sure, corresponded to a state of higher biological integrity than is shown by the majority of modern orchids.

We cannot, therefore, make their present situation the measure of that occupied by the orchids in earlier stages of their history. At one time, no doubt, what they received by way of "remuneration" for their biological services, differed in character from what they receive to-day. Economic laws being eternal, we may conclude that in "the good old times," with more "patriarchal" integrity, the orchids reaped the fruits of "Norm- rather than of "Luxury"- Symbiosis," and that they were differently circumstanced accordingly. The fungi, for instance, we may infer, played a more subordinate rôle *vis-à-vis* to the orchid ancestors than they do now.

In order to facilitate an understanding of what is to follow, it will be as well here to examine a little closer the question regarding the predisposition to disease on the part of the Monocotyledons. The phylogenetic origin of this class of plants may be a matter of speculation, but if we consider their various disabilities from the point of view of Bio-Economics, we may be able to bring a little more discernment into the matter than has hitherto prevailed and concurrently reach a better understanding of the course taken by the orchids.

In a very interesting paper on "*Vegetable Degeneration*" (*British Review*, Oct., 1913), the Rev. Prof. George Henslow tells

us that the Monocotyledons show characters which are acquired by living in water, and are in this respect just like aquatic Dicotyledons, from which, he thinks, they have descended—"though many monocotyledons have become land plants and regained all the structures necessary for an aërial existence."

The fact of an aquatic origin would indeed go a long way to account for backwardness; for, as I have already emphasised in the case of animals, they are more improved upon the land because there the chances of Symbiogenesis are much greater, since the land offers greater security and better opportunities for the progress of socio-physiological processes than the water. And, of course, what is true of animals, also holds good *pari passu*, of the correlated development of plants.

As an interesting instance of the degrading effect of an excess of water upon plants, Prof. Henslow mentions the little sun-dew, a dicotyledonous plant of the *Drosera* family, which

lives in the saturated bog-moss, and has the most feeble roots possible, so that it is not likely to get much nourishment. To compensate for this, it has acquired the habit of, and proper structures for, catching insects and so procures the necessary supply of nitrogen. It is found by experiment to especially increase the reproductive powers, as these are very sensitive to degenerating influences.

Although this case apparently only illustrates the physical effect of water, yet we have here at the same time, and in an important sense, a socio-physiological effect, since there is retrogression in bio-social relation. It is customary to represent it as though the habitat were a matter of chance; but in many or perhaps most cases this is not so. The habitat represents the choice of the organism, which, in this case, was desirous of indulging in in-feeding propensities, being inclined to a lazy compliance with low conditions as afforded by life in, or close to, the water. To say that the sun-dew cannot get much (normal) nourishment because it has feeble roots, may be, and I believe is, putting the cart before the horse. It is as likely as not that the habit of indolent in-feeding of some kind or other has led by slow gradations to a weakness and finally a degeneration of the roots.

Darwin stated that if a plant of *Drosera* may be said to drink by its roots, "it must drink largely, so as to retain many drops of viscid fluid round the glands, sometimes as many as 260, exposed during the whole day to a glaring sun," which again connects the habitat with the appetites; for it is the function

of these glands, *inter alia* to digest the captured insects. I would, therefore, rather explain the habitat by the appetites than *vice versa*. The sun-dew family, in my opinion, suffers from an in-feeding diathesis. Nor is it a "physical" explanation, as some imagine, to say that the sun-dew's reproductive powers are increased because they are sensitive to degenerative influences, when all that has happened is this: the symbiotic restraint has gone and with it the restraint of propagation. This, however, so far from being a genuine increase of reproductive power, is only equivalent to a dissociation of such power and produces weakness.

As the matter is one of some importance, I feel justified in quoting Prof. Henslow further, and at some length:

The root of the land plant is solid with a central and circumferential mass of cellular tissue, together with clusters of wood-fibres arranged in a circular manner. In the aquatic root large holes occur in the former tissues, and the wood is greatly reduced in quantity, as the water supports the plant. As roots must be well aerated for respiration some trees growing in swamps have their roots with ascending parts like knees or poles rising out of the ground, which are more or less hollow and filled with air. In herbs, the pith of stems is like a sponge, only the holes are filled with air, as occurs in those of rushes; so, too, is the surface of the root of the marsh samphire, so abundant on salt-marshes. These are compensating structures to overcome the injurious effects of too much and insufficiently aerated water.

Thick stems, such as the rhizomes of water-lilies, and the aerial stems of palms, as well as all other monocotyledons, have very degenerate characters, *i.e.* if we regard an oak tree, for example, as the type of what a stem should be. Timber trees put on annual cylinders of wood, thereby making the stem strong enough to support their own weight and that of the mass of foliage.

If life in the water is thus in many ways easier than upon the land—the plant being suffered to exist epiphytically as it were upon the supporting water—it is yet not without grave disabilities and dire handicaps. It is better for a plant to live on the land and to support itself by vigorously drawing on soil and atmosphere. There is almost a sociological turn in Prof. Henslow's passage when he refers to a "type of what a stem should be." This desideratum is fulfilled where we have a plant duly drawing on the mineral substances of the soil and thus evolving a complete vascular system—a matter of the utmost importance to organic life generally, which should be consistently taken into account.

"In aquatic stems," Prof. Henslow goes on to say, "the

individual vascular bundles which collectively make up the cylinders of wood, are all, so to say, dislocated, and a cross-section shows isolated dots." And he shows that the absence of the "cambium" is an indication that monocotyledons have descended from aquatic dicotyledons by a process of degeneration. "Many are now terrestrial by re-adaptation to land, but they have never lost all the characters acquired from water."

We must also bear in mind the great similarity which "aquatic" bears to parasitic degeneration, a similarity which is enhanced by the force of my previous contention with regard to the character of "aquatic" degeneration, *i.e.*, as partly founded upon sociological backwardness, due to general insecurity of life, and a wide prevalence of predatory instincts.

If, as Prof. Henslow states, a weakening effect is produced in the case of submerged plants through the water supersaturating the living protoplasm, the fact of vegetable backwardness in Symbiosis is equally apt, through a concatenation of partly sociological and partly physical causes, to produce similar or identical effects, which weaken the protoplasm. Every lapse in Symbiosis results in a loss of useful socio-physiological "concentration," apt to expose the protoplasm instead to impediments of various kinds; for, just as idleness destroys chastity, so the suspension of useful interaction perverts the austere composition of the protoplasm.

The protoplasm, according to the same botanist, can be artificially improved by dissolving nutritive salts in the water, which has the effect of withdrawing the excessive water, and this recalls Prof. Bernard's discovery in the case of the orchids, that there is an equivalence of high concentration and Symbiosis.

Symbiosis, of course, has to do with innumerable physico-biological services and counter-services; so much so as to justify us to exalt these services altogether to the sociological level rather than conversely to lower Symbiosis to the physical. We saw that in *Drosera* the need for excessive water was correlated with the appetites of the plant, with its associated biological activities; and in a similar way the need of a moist habitat and of reservoirs of water depends upon the biological activities—having regard to food and to pollination—in the case of the orchid. To supply a concentrated nutritive solution, thus withdrawing surplus water, may have the effect of invigorating an "autonomous" *i.e.*, "uninfected," orchid, which is otherwise

habituated to corresponding releases by a fungal partner. True, the stimulation is physical, or chemical; but surely it also partakes of the nature of socio-physiological substitution; for man performs the part of the fungus. In any case, both in *Drosera* and in orchid the presence of excessive water is not without sociological significance. That *Drosera* has become an in-feeder may be seen from the fact that apart from insects, its glands also absorb matter from living seeds, which are injured or killed by the secretion; and, according to Darwin, the glands also absorb matter from pollen, and from fresh leaves. No wonder, therefore, with such degrading habits, the protoplasm fails to be healthily constituted and weakness ensues.

All of which shows that if we wish to arrive at a correct appreciation of any particular form of Symbiosis, allowance must first be made for the nature of the existing disabilities, if any, for which redress or compensation is sought by means of mutual aid. Symbiosis is an ideal method for remedying disabilities; but inasmuch as those disabilities are primarily due to faulty social methods, *i.e.*, some perversion of fundamental or "Norm"-Symbiosis, what new methods of Symbiosis may be adopted, are often but secondary in importance. The new form of symbiotic adaptation, in other words, may have only a local and a merely expedient purport, and even be leading away from Symbiogenesis, which, as we have seen, proceeds less by expedient than by "social" ways; and if it is thus apt to lead away from the good pathway of life, the value of such secondary Symbiosis is, to say the least, doubtful. This comment applies, I believe, to orchidean Symbiosis with the fungi, and likewise to the case of Convolutal Symbiosis with (saprophytically inclined) algæ, which "Plant-Animalism" I have already, in *Symbiogenesis*, set down to a retrogressive form of Symbiosis. The connection of such secondary forms of Symbiosis with disease is due to the fact that they impair a more important form of Symbiosis, upon which health primarily depends. I believe Prof. Bernard's chief error consists in his treating as primary, a secondary form, of Symbiosis.

The French Botanist's "ladder" of orchidean Symbiosis leads from *Bletilla* to the tribe of the Cattleyas, many of which are cultivated in green-houses. We are told that:

Le chemin parcouru peut en définitive s'apprécier par des signes assez nombreux. Les embryons des graines ont régressé et ne présentent plus

de différenciation morphologique, ils ont en même temps perdu la faculté de se développer d'une manière autonome. La symbiose est nécessaire et non plus facultative ; en conséquence il n'y a plus qu'un seul mode de développement possible et l'existence d'un protocorme est constante. Au lieu enfin qu'il y ait formation plus ou moins tardive d'un bulbe distinct du protocorme, c'est ce protocorme même qui se transforme précocement en tubercule embryonnaire. Malgré ces conditions et ces formes nouvelles des phénomènes initiaux du développement, le mode de végétation à l'état adulte n'a pas sensiblement varié.

There is thus considerable evidence of retrogression, and real Symbiosis seems on the way to perversion rather than to perfection.

Still greater dependence of the orchid upon the fungi is shown by *Odontoglossum*, which, from the very beginning of life, presents no period of "autonomy," since infection takes place before the seedling has by means of phagocytosis completely destroyed the fungi in the protocorm. Prof. Bernard thinks that this species is "plus hautement adapté à la symbiose que les Cattléyées," and he seeks to connect this with the fact that *Odontoglossum* is, according to him, the higher evolved plant of the two. But though there may be increased "adaptation," it does not follow in my view that the character of the intimacy has improved in any real sense. A good test would be to examine whether Norm-Symbiosis has improved or deteriorated with any particular intimacy of this sort. "By their fruits shall ye know them." The Sarcanthineæ differ, so Prof. Bernard tells us, from the other orchids which he has studied, by the singular conformation of their protocorm and also by their mode of vegetation in the adult state. The latter difference, he thinks, is another symptom of the high degree of symbiotic adaptation prevailing amongst them. These "highly evolved" orchids not only show a very early formation of roots, but these roots take on an unaccustomed importance ; so much so that we find them in the adult state to attain a degree of development and of persistence not to be found elsewhere amongst epiphytic orchids (examples : *Taeniophyllum*, *Polyrrhiza*, *Chiloschista*, *Vanda*).

The roots are a long time in developing and are possessed of remarkable vitality in all seasons, all of which markedly differentiates the Sarcanthineæ from most other orchids, which show instead successive and distinctive outgrowths of roots which generally do not live longer than a year : "Or, au point de vue de la symbiose, le grand développement et la persistance des racines entraînent de notables conséquences."

What are these important consequences? On the one hand the infected tissue gains considerable importance *vis-à-vis* to the *ensemble* of the un-infected tissue of the plant. This Prof. Bernard would interpret as meaning that the respective orchids have to suffer more intensely than others the action of their "commensals."

He argues from the protracted growth and the persistence of the roots that the plant harbours living fungi during the whole course of its life :

L'état de symbiose devient pour elle une condition de vie continue au lieu de n'être comme chez les Orchidées à poussées successives de racines fugaces, qu'une condition périodique. Il est pratiquement facile, par exemple, de trouver en toute saison des racines de *Vanda* abondamment infestées et d'en extraire des pelotons de mycélium capables de développement. Cette continuité de l'infestation témoigne assurément d'une adaptation à la symbiose approchant de la perfection.

Yet I do not think that Prof. Bernard has fully established the thesis that the Sarcanthineæ owe their comparatively high evolution to fungal Symbiosis, which may have been but one component, and a relatively late and minor one, whilst the result was in reality due to the long protracted action of Norm-Symbiosis with all it involved in symbiotic moderation and in the establishment of symbiotic sense. There may have been comparative abstinence from in-feeding or from excessive water-drinking, or other factors may have existed, such as go in support of Norm-Symbiosis, whilst moderating fungal Symbiosis. The presence of fungi *per se* does not prove that they play everywhere the same part. This follows even from Prof. Bernard's own description of the conditions of "Symbiosis." These particular types of epiphytic orchids may have succeeded better than others in keeping the fungi in their proper place, albeit in close union, whilst treating them even to some considerable symbiotic forbearance. That is to say that the orchids in this case have been able to make such provision as to accommodate useful servants without the least harm to themselves and to Norm-Symbiosis, and so as to interfere least with progress. On no account can we accept the theory that a "Symbiosis" need only to become "continuous," *i.e.*, attached, in order to be perfect or favourable to progressive evolution. Neither do the fungi really live continuously with the Sarcanthineæ; and Prof. Bernard has to admit that in the case of *Phalaenopsis* and *Vanda* :

les premières racines ne s'infestent pas au contact des tissus du

protocorme quand elles en sortent, mais sont seulement envahies par les champignons qu'elles rencontrent dans le compost et qui y ont vécu plus ou moins longtemps librement

(which latter condition of "autonomy," however, as is elsewhere shown in the paper, frequently causes them to lose their "virulence"). And we are further told :

Sans doute chez ces plantes, comme chez les *Vanda*, où j'ai vérifié le fait, la tige adulte reste indemne de champignons et chacune des racines qu'elle produit doit s'infester au contact du substratum d'une manière indépendante. A ce point de vue donc, malgré le progrès qu'elles présentent par rapport aux autres orchidées épiphytes, les Sarcanthinées réalisent une adaptation à la symbiose continue moins parfaite que celle dont certaines Orchidées terrestres, comme le *Neottia Nidus-avis*, donneront tout à l'heure un exemple.

It is thus clear that mere "continuity" cannot be considered a reliable criterion of the value of Symbiosis.

The Sarcanthineæ, however, are remarkable for a mode of vegetation quite exceptional amongst orchids—a mode "manifestement secondaire et non primitif puisqu'on le rencontre chez les plantes les plus évoluées de la famille."

This new departure of growth chiefly concerns the stalk, and Prof. Bernard is of the opinion that the phenomenon is connected with the continuity of fungal Symbiosis. According to his own description :

Au lieu qu'il pousse des tiges aériennes successives, enchaînées en sympode par l'intermédiaire de portions de rhizomes, il y a ici une tige unique à croissance indéfinie, qui naît du premier bourgeon différencié sur le protocorme et qui produit seulement des inflorescences latérales. La végétation est, comme on dit, devenue "monopodiale."

In some cases the stalks may grow considerably, becoming woody and so as to give the plant almost an arborescent appearance :

Les *Vanda suavis* et *tricolor*, dont on voit souvent dans les serres des exemplaires assez vigoureux, donnent une idée de ce mode de végétation, mais il s'observe sous une forme plus typique chez de rares espèces comme l'*Angraecum eburneum* ou le *Vandopsis lisso-chiloides*. D'après le Manual de Veitch, cette dernière Orchidée peut produire des tiges ligneuses robustes de trois à quatre mètres de haut. Dans les îles Philippines, où elle vit à l'état spontané, on la rencontre tout près de la mer, attachée par ses solides racines à des rochers exposés au plein vent. Elle atteint, en somme, un état arborescent qui est comparable à celui de plus d'un palmier.

All of which, I think, is of some little interest as illustrating what possibilities there are in the path of Symbiosis, although these are greatly enhanced in the case of Norm-Symbiosis, which,

whilst involving more balanced and generally more widely useful work, also provides more reliable, more endurable and more elevating stimuli than fungal Symbiosis. On Prof. Bernard's view it would almost follow that *Neottia*, with its "continuous Symbiosis," should come nearest amongst terrestrial orchids to rivalling the status of the palm tree, which, of course, it is far from doing. Neither, in my opinion, could *Vandopsis lissochiloides*, in the Philippines, achieve its feats of monopodial growth if it lived *Neottia*-like in and upon the humus. There are evidently different developments of monopodial growth, just as there are different kinds of Symbiosis, though the difference be unrecognised by present classifications.

Prof. Bernard thinks that the replacement of sympodial by monopodial modes of vegetation through the continuous development of one and the same bud (instead of periodic development of successive buds) is one of the most interesting episodes in the history of the orchids. His belief that the event is due to the progress of (fungal) Symbiosis and coincides with the change from periodic to continuous Symbiosis, has led him to suggest the still bolder hypothesis that :

La tendance à la végétation arborescente, que manifestent certaines Sarcanthinées chez lesquelles ce mode de végétation monopodial s'est institué, est un fait des plus suggestifs, dont l'existence me porte à croire qu'on pourra un jour découvrir un lien entre les progrès de l'évolution en symbiose et l'apparition des plantes arborescentes. Mais assurément l'étude des Orchidées ne peut fournir que des documents imparfaits pour la solution de ce problème général, et ce que j'en déduis ici n'est qu'à titre de suggestion.

Whilst agreeing with the reservations, I would also agree with the hypothesis itself, provided that by "Symbiosis" is meant Norm-Symbiosis, which alone is capable of permanently providing the wherewithal required to achieve effective arborescence.

It is not a little curious at this stage of the disquisition to find Prof. Bernard unwittingly paying a tribute to Norm-Symbiosis as the great determinant of plant-evolution. For, in support of his contention that the *Ophreæ*—the next group of orchids examined by him—are rather highly evolved, he stresses the fact of adaptation to insect-fertilisation, which fact is manifested by the conformation of the respective flowers. But, surely, it is this class of adaptation, with all it involves in progressive socio-physiological evolution, that represents the Norm of Symbiosis in the world of life. Compared with it Prof. Bernard's "Symbio-

Commensalism" is but a trivial, if not retrogressive, form of organic association from which we cannot expect great results of evolution.

Open-mindedly enough, Prof. Bernard concedes, as an alternative to his general view on the subject, that many of the special structures of the orchids, so far from being due to "Commensalism," may be merely due to epiphytism and saprophytism :

Je ne nie pas que des conditions diverses indiquées par ces modes de vie aient pu avoir une action sur l'évolution des végétaux qui les acceptent ; quelques traits de leur organisation peuvent sans doute s'expliquer ainsi.

And he has the intuition to see that organisms may somehow become liable to what I consider retrogression, because of their having to propitiate associated parasites or *quasi*-parasites. To quote his own words :

On peut aller plus loin et penser que l'aptitude à l'épiphytisme ou au saprophytisme a pu se développer chez les Orchidées, originellement terrestres et non saprophytes, justement par suite de l'action sur ces plantes de leurs champignons commensaux, la symbiose ayant entraîné à la fois l'apparition de caractères morphologiques nouveaux et de dispositions physiologiques particulières.

If Prof. Bernard had but gleaned his lessons from Symbiosis proper instead of confining himself to "Symbio-Commensalism!" Whilst it is quite true, and even specially significant, that life and evolution are pre-eminently determined by the nature of the organism's associations, yet we may be certain that the extreme determination of the proud orchids by the lowly fungi—a determination away from Norm- and increasingly towards Luxury-Symbiosis—must have been preceded by some morbid factor, by some predisposition to "infection" on the part of the orchids. And this predisposition, in my view, was due to an incipient form of in-feeding. An in-feeding diathesis, however mild at first, determined the retrogressive evolution of the orchids. The fungi merely played an adventitious part in it; their presence, *inter alia*, augmenting the craving for in-feeding, *i.e.*, for saprophytism.

To the fungi, the symbiotic association with the orchids for the most part means strenuousness and abstinence from pronounced saprophytism.

Whilst telling us that they are apt to lose their "propriétés

physiologiques " *vis-à-vis* to the orchids, namely, when, as is often the case in greenhouses, the fungi succumb to the temptation of living " *en saprophytes* " (as unrestrained in-feeders), Prof. Bernard has some observations with regard to the prevention of disease in cultivated orchids, which remarks generally apply in the case of prevention. This is what he has to say :

Des pratiques de culture mal comprises peuvent avoir pour effet de sélectionner ces races inactives au détriment de celles dont l'activité se maintient par la symbiose.

In other words, we must aim at providing conditions of symbiotic moderation ; and if we wish to be truly successful in Horti- as in Agri- or " Physi-" culture, we must side with the good and strenuous (cross-feeding) rather than the bad and indolent (in-feeding) micro-organisms. More pertinently still, we are told :

La pratique des rempotages peut ainsi devenir néfaste, or elle est fort en usage dans les serres soigneusement tenues où l'on se préoccupe de cultiver les Orchidées dans un compost sain, toujours recouvert de *Sphagnum* vivant et frais. On adjoint d'ailleurs à cette pratique des soins divers de propreté et de désinfection qui ont un rôle utile pour la défense des plantes contre leurs parasites accidentels, mais qui peuvent éventuellement aussi nuire à une existence régulière de leurs commensaux habituels. Des précautions trop attentives pour la culture des plantes adultes peuvent devenir nuisibles pour la réussite des semis. Il est bien connu en fait que les semeurs les plus heureux ne sont pas toujours ceux qui tiennent leurs serres avec le plus de soin.

In the place of a reduction of the in-feeding, we supply " cures," many of which, as I have been at some pains to show in *Symbiogenesis*, are worse than the disease. I have insisted that in order to understand the requirements of an organism, or to determine a " standard-metabolism," we must first make allowance for the needs, real or fictitious, symbiotic or parasitic, of the associated organisms, and this is seen to be corroborated by Prof. Bernard's experiences.

Seeing that the symbiotic association acts as a great stimulant of fungal activity, Prof. Bernard speaks of an " exaltation de l'activité des champignons par la symbiose " ; but instead of regarding the phenomenon as a healthy development, he compares it to " la virulence des micro-organismes pathogènes," stating in fact that " le degré d'activité d'un Rhizoctone, comme le degré de virulence d'une bactérie pathogène, révèlent sans doute, sous

deux aspects différents, le degré d'adaptation de parasites à leurs hôtes."

The underlying fallacy, of course, is that Parasitism, and not Co-operation, is the fundamental principle of life; that all Symbiosis indeed began with Parasitism—errors which are widely prevalent amongst Biologists. Were it not that Prof. Bernard had confined his study to a rather "exotic" case of Symbiosis, he would have had little difficulty in meeting with more harmony and less instability. The wonder is that there exists so much harmony when we are faced on the one hand by an eccentric family of monocotyledonous plants, which, by their strange peculiarities, their strange needs and shortcomings, hold a precarious place in the world of life; and on the other hand by a low and degenerate organism showing almost incalculable fluctuations of character. If two such species can combine with a tolerable measure of success, we can only surmise that it is one of Nature's fundamental ways of extending her sanction to co-operation wherever possible.

Prof. Bernard had discovered that "la vie dans un embryon peut donc rendre à un mycélium complètement atténué une partie de l'activité qu'il avait perdue." In other words, the spirit of Symbiosis is infective. The relatively stronger disposition for Symbiosis on the part of the higher plant, under adequate conditions, stimulates the weaker disposition of the lower plant. More generally expressed, symbiotic momenta operate so as to encourage, or, where partly lost, to restore, the disposition towards (widely) useful work. Again we may thus conclude that the symbiotic relation provides a fundamental education fitting the organism for useful organic citizenship. It reads as a further corroboration of this view when Prof. Bernard, as the result of his experiments, tells us that uniformly "les champignons les plus actifs étaient toujours ceux qui avaient le plus longtemps vécu en symbiose."

As a result of further experiments bearing on the "influence du degré d'activité des Rhizoctones sur l'évolution des Orchidées," Prof. Bernard inclines to the view that the fungi

grâce à l'activité même qu'ils acquéraient progressivement par la symbiose, aient réussi à imposer aux Orchidées des modes de végétation favorables à une symbiose de plus en plus parfaite.

Apparently it was this experience, more than any other, that led him to speak of a "Selection" of the orchids by the fungi.

But the facts are capable of a different interpretation. The fungi, in my opinion, only gain paramount influence inasmuch as the orchids, *qua* in-feeders, have become indolent and degenerate; whilst the increasing intimacy does not constitute genuine progress in Symbiosis at all.

That in Norm-Symbiosis the partners have to make mutual concessions and to some extent mutually to determine each other, is, of course, a different matter—one that emerges from the study of such Symbiosis without the need of referring to "Selection" at all.

A similar criticism applies to the following of Prof. Bernard's statements, though feasible enough by itself:

La possibilité de progrès corrélatifs de l'activité des champignons, de la symbiose et de l'évolution des Orchidées, est donc théoriquement concevable. Mais si elle correspond à une réalité, il doit en rester des preuves; on doit trouver chez les Orchidées les plus évoluées des champignons plus actifs que chez les Orchidées les plus primitives; il doit y avoir un rapport constatable entre le degré d'activité des champignons et le degré d'évolution de leurs hôtes.

Granted such correlative progress, there still remains the question: Are we on the whole dealing with progressive or with retrogressive evolution, and which are, in either case, the respective criteria? Is the correlation connected with healthy or with morbid affinities? And what is it that determines sanctions, or limits, in such correlated evolution?

In the course of his investigations, Prof. Bernard interchanged the "infecting" fungi, such as *Rhizoctonia repens* and *Rhizoctonia mucoroides*, and this is what he found: "L'ensemble des expériences montre clairement en définitive que le degré d'activité des champignons est plus important pour les résultats que la nature même de ces champignons."

Again, this is what one would expect on the view that the study of behaviour is more important than that of classification. It is necessary, however, to add that the degree of "infective" fungal activity is not altogether one-sidedly determined; it is to a large measure determined by the biological activities of the orchids, in particular their feeding habits. The activities of associated orchids and fungi in fact are mutually determined. The danger-point arises when they are too narrowly determined, or when one or the other partner becomes unduly preponderant,

and so as to "extremely determine" (devour) the other. The same reservation applies to the following remark :

- Si les variations d'activité des champignons endophytes ont bien eu, comme je crois, une importance essentielle pour l'évolution des Orchidées, on peut penser que l'adaptation de ces plantes à des conditions variées d'existence a été aussi une conséquence de l'action de leurs commensaux.

I have already expressed, in a previous chapter, the idea of such determination of organism by organism. It only remains to introduce a little more precision. The fungi have had *some* importance in the (late) evolution of the orchids. Once admitted as partners, they have *to some extent* determined the adaptations of the orchids. The degree of determination depended upon the degree of susceptibility shown by the orchids. The more the latter became indolent in-feeders, the more they were obliged to shape their adaptation in accordance with the needs, real and fictitious, of their associates, and in a manner irrespective of their own real good.

The description furnished by Prof. Bernard of the penetration of the orchids by the fungi rather suggests that even at the eleventh hour, *i.e.*, with intimacy so close as almost to be parlous, the symptoms are yet such as to suggest a state of Symbiosis rather than one of Parasitism. He speaks of "régions de passage" in the orchid seedling (regions through which the fungi have leave to pass in or out), attributing to them a double "privilège" : "elles peuvent d'une part attirer les champignons et, d'autre part, elles n'opposent qu'une faible résistance à leur pénétration." It is admitted in fact that the orchids "attract" the fungi, though, as we are told, not through a great distance. What is more, we are at last reminded that at bottom some economic purpose is to be served by Symbiosis, thus : "les régions de passage sont précisément les régions superficielles les plus perméables, ayant le rôle essentiel pour l'absorption ou plus généralement pour les échanges d'eau et de substances dissoutes entre la plante et le milieu extérieur."

All of which suggests a relation of neighbourly mutual exchange as the original basis of the intimacy, the fungal mycelia learning to increase their surface by means of clusters, which I believe, gives increased scope to the operation of surface-tension and thus supplies more completely the requirements of the orchids. The fungal cluster would thus appear as the symbiotic parallel and complement of the orchidean "région de passage,"

and although the cluster eventually was to arise within the orchid, yet even there its existence must be dependent upon some kind of interior "région de passage," on osmotic processes, etc. We are told that

on peut supposer que ces régions éminemment perméables sont capables d'excréter des substances solubles attractives pour les champignons qu'on sait sensibles à des actions chimiotropiques.

This view of the matter rather contradicts the idea of a one-sided "Selection" of the orchids by the fungi; and it suggests instead the development of considerable symbiotic awareness of, and preparedness for, each other's needs on the part of the two organisms, a very different thing from Selection. Neither is it suggestive of "Selection" by the fungi when we are told that:

Si des embryons d'*Odontoglossum* se trouvaient sur un milieu où co-existent les divers champignons que je leurs offrais isolément, ils pourraient faire un choix entre eux et se laisser pénétrer seulement par les plus actifs. Cette faculté d'exercer un choix entre divers champignons, peut éventuellement limiter les risques auxquels les embryons d'Orchidées doivent être communément exposés quand ils rencontrent à la fois des champignons utiles ou nuisibles pour leur développement.

So far then from there being a "Selection" by the fungi, we have here rather a case resembling that of many flowers which permit access only to those nectar seeking insects which render adequate counter-services to the plant. In both cases the discriminating agent is the higher plant; and in both cases, the sanction of Nature depends upon the bio-economic usefulness of the union. The "risks" run by the orchids, alluded to by Prof. Bernard, do not, strictly speaking, begin with the meeting of a particular fungus; they began with the habit of in-feeding which provided the "soil" for infection, inasmuch as the habit universally makes for "surpluses" of an undesirable kind—the surpluses of dishonest labour.

Without a court of appeal, such as is constituted by Bio-Economics, we shall for ever continue muddling with "Selections" and "Adaptations," without ever arriving on firm ground.

Failing Bio-Economics, the French Botanist feels again obliged to plunge into Pathology; and, under the head of "Infestation Primaire, Vaccination," he ventures upon certain interpretations, which are for the most part, I believe, based

upon a misunderstanding of the nature of Symbiosis, and of the laws of biological action and reaction.

Comme je l'ai dit dès le début de ce mémoire, la réalisation de la symbiose est surtout un effet du hasard ; si les Orchidées ne produisaient pas chaque année d'innombrables semences, elles seraient vouées bientôt à la disparition. La symbiose est une forme exceptionnelle et apparemment paradoxale de maladie infectieuse, mais qui n'échappe pas cependant aux lois communes de la pathologie. De même qu'une première atteinte bénigne d'une maladie infectieuse accidentelle peut préserver un être d'une atteinte plus redoutable, de même l'infestation par un champignon atténué peut " vacciner " un embryon d'Orchidée et prévenir l'infestation par un champignon plus actif. Mais, dans ce cas singulier, l'accoutumance aux parasites est devenue assez parfaite pour rendre la vaccination néfaste ; l'infestation prolongée, qui entraînerait ailleurs un pronostic grave, permet seule ici le développement.

Instead of which it should have been simply shown that we have here to do merely with " un symbiose de luxe," and not with the primary and normal form of Symbiosis so widely and usually exhibited by the strenuous green plant. It should have been pointed out, free from all " pathological " jargon, that the life of the orchids is precarious precisely for the reason that they have placed too much reliance upon a particular form of Symbiosis, which involved comparative neglect of service in Norm-Symbiosis. If it may be said of symbiotic adaptation that it is " paradoxale de maladie infectieuse"—this is true in the sense that such adaptation represents the very antidote of disease, the very emblem of health. Much in the same unwarrantable way in which orchid-*cum*-Fungus Symbiosis is here described as belonging, though perhaps somewhat paradoxically, to the region of Pathology, so it has hitherto been customary amongst Biologists to pronounce the case of the lichen as one closely related to Parasitism. Recent research, however, has shown that in the lichens, penetration of the living gonidia by fungal hyphæ occurs very seldom, and that a theory of Parasitism based upon its occurrence has very little evidence to support it. The symbiotic nature of the lichen-organism is generally accepted by lichenologists. We have seen that the activity of most lichens is in harmony with the law of Concord, and that they are accordingly marked by great usefulness and remarkable longevity and health. If it be that nevertheless the " lois communes de la pathologie " are here applicable, this is for the reason, I believe, that such laws represent mere re-statements of fundamental

socio-physiological truths, and in the sense that Pathology, rightly interpreted, teaches what Physiology should be. Prof. Bernard's application of Pathology, however, I fear, can only be regarded as "un tour de force." The orchidean embryo is no more to be regarded as "vaccinated" by the entrance of a mycelium, than the egg is "vaccinated" by the entrance accorded to a sperm. And it seems that the orchid embryo has no more *gusto* for an alien mycelium than the ovum usually has for an alien germ. The amenities of the case are precisely those one would expect on the view that genuine co-operation and what this involves in mutual preparedness and mutual forbearance were the aim of Nature. Neither, I believe, is it legitimate to speak of "une atteinte bénigne d'une maladie infectieuse accidentelle." Infectious disease, I hold, is never a matter of accident, but one of "soil"; bad conditions of "soil" being due to faulty biological behaviour—the bad action producing the bad reaction upon the organism. And it is, in my opinion, absurd to call an infection "bénigne" because the defence of the body is as yet a match for the attack of the respective parasites and because the body, on being fore-warned, may to some extent even prove fore-armed. But to be pronouncedly liable to infection is always a parlous condition, and the incidence of infection is only too apt to follow in the wake of the liability. With an occurrence of infection, the organism is obliged to re-arrange its powers of defence. But whether such re-arrangement is to entail a true strengthening of what one might call "Norm-immunity," or only a "makeshift-immunity," unattended, that is, by a concomitant reduction of the liability, remains to be seen in every case. Nature aims above all at the maintenance of integrity, which is more vital than the merely expedient survival of individuals, and the manifold symbiotic bonds established and profoundly sanctioned by her, cannot be lightly set aside with experiments aiming at "make-shift" immunisation. To tinker with old-established bonds, sacred to Norm-Symbiosis, irrespective of "Norm-immunity" and "Norm-integrity"—the integrity of the honest, thrifty and unencumbered organism—is only putting off the evil day and preparing the way for worse disasters to follow.

The case of the orchids shows that the fungi are attracted by the surplus products of orchidean metabolism, the quality of these products being in turn determined by the feeding habits

of these plants. The odour of many orchids is strong and offensive, and in this they are like the " plant-animal " *Convolvula*, the case of which was considered in *Symbiogenesis*. It was there pointed out that such offensive odour was indicative of an in-feeding diathesis, and, further, that scavengers and beasts of prey are generally attracted by the odours emanating from diseased individuals. In-feeding habits, therefore, are not the means of preventing infection or of supporting ideal partnerships. We have seen good reason for regarding the orchids, which have surrendered " pivotal " vegetable industry, whilst contracting the habit of in-feeding, as partly diseased organisms. If, as a result, they are liable to infection, this is in keeping with their degeneration; if, on the other hand, they have partly succeeded in checking or controlling would-be parasitic fungi, this is to be credited to the survival amongst them of at least some good sense, dating back in its origin to ancestral Norm-Symbiosis and *pro tanto* due to something the very opposite of parasitic or pathological relations.

In Prof. Bernard's view, what means of limiting the " infection " are possessed by the orchids, are due to the exercise of " phagocytosis," which is " capable à lui seul d'assurer l'immunité quand les cellules de passage ont laissé pénétrer le mycélium."

But, we are assured, that this is only part of the story, and :

Dans tous les cas au contraire où les jeunes Orchidées périssent rapidement par suite d'une infestation, la phagocytose n'entre plus en scène, ou ne joue du moins qu'un rôle effacé. . . . Si l'on se bornait à comparer ces deux catégories de cas extrêmes, il pourrait sembler que la phagocytose a un rôle prépondérant pour assurer l'immunité. Mais entre le cas de l'infestation bénigne, bientôt enrayée par la digestion des champignons dans les phagocytes et le cas de l'infestation rapidement mortelle avec phagocytose insignifiante, il y a le cas intermédiaire de la symbiose où la phagocytose s'exerce sans arrêter la progression des champignons et où cependant les plantes ne succombent pas.

All of which is merely a roundabout way of saying that definite conditions of mutual tolerance and mutual forbearance have to be fulfilled before we can have a case of genuine mutual usefulness, such as constitutes Symbiosis. May we not assume that the body makes changes in its general means of defence according to different requirements and in accordance with the nature of every new relation? If Prof. Bernard had not confined himself to the study of second-rate Symbiosis, he would have discovered that Symbiosis is the alternative to " struggle for

existence," and that genuine biological Symbiosis rather strengthens internal Symbiosis than provokes it to costly reactions. We are told: "L'impuissance de la réaction phagocytaire est un des caractères les plus nets qui différencient la symbiose des états voisins."

But "impuissance" being merely a "manière de voir," and not one corresponding to reality—Symbiosis tending to increase rather than to diminish the resisting powers—Prof. Bernard is obliged to improve upon the conception on the next page by having recourse to his paradoxes, thus :

Malgré cette impuissance de la phagocytose, il persiste bien dans la symbiose une certaine immunité, puisque les champignons ne parviennent jamais à infester les sommets végétatifs et qu'en définitive la plante arrive à produire des tiges, des fleurs, des fruits et des graines indemnes. C'est là, pour ainsi dire, une forme ultime de l'immunité, dans laquelle la plante doit mettre en œuvre tous ses moyens de défense pour préserver ses tissus essentiels. Puisque la phagocytose n'est plus alors un moyen efficace, il faut bien qu'il en existe un autre ; on doit le découvrir en cherchant les raisons qui obligent pour ainsi dire les champignons à régler leur marche sur la marche même du développement des plantules.

It is thus clear that "impuissance" is relative, and only another way of denoting the concession made by the orchid in return for services rendered in Symbiosis. In other words, the fungus, being duly checked and under restraint in one direction, may enjoy some freedom of action in another. If the fungus will but be duly useful, it need not be slaughtered by either "phagocytosis" or "immunity," but it may instead be admitted into co-partnership. If Symbiosis involve the balancing of "defences" and of concessions, we need not see anything paradoxical in the fact that the orchid partly curbs and partly encourages the fungus, nor in the fact that the orchid, whilst "susceptible" in the absence of its fungus, yet changes such susceptibility, or receptivity, once a fungus has penetrated. And this brings us again to the imposition of "pelotonnement," the second important means in the power of the orchids of limiting infection on the part of the fungi. Fungi which will not suffer themselves to form clusters, are not capable, it seems, of co-operation with the orchids, because they fail sufficiently to respect the autonomy and the true interests of the orchids, thus violating a fundamental bio-economic law of Concord. We are told that :

En fait, dans tous les cas d'infestation mortelle que j'ai précédemment cités, les champignons abandonnaient tôt ou tard ce mode de végétation ;

(namely, of cluster formation) dès lors les filaments, s'accroissant en tous sens et plus ou moins en droite ligne, envahissaient indifféremment tous les tissus. La clef du problème de l'immunité dans la symbiose doit être dans la découverte des conditions qui déterminent la formation des pelotons mycéliens.

What, again, are the conditions determining the formation of clusters? At first Prof. Bernard thought of a mechanical explanation of the phenomenon, which, subsequently, however, proved insufficient, and he tells us :

Le pelotonnement est un des modes de végétation possibles pour les Rhizoctones ; il est rarement adopté par eux dans la vie libre, mais il leur est au contraire continûment et régulièrement imposé dans la symbiose. Puisque la structure cellulaire des plantes n'est pas la cause mécanique de cet état des choses, on ne voit guère pour l'expliquer que des raisons physico-chimiques. Il doit s'agir là d'un phénomène lié à la nature de la sève intracellulaire des plantules et c'est sans doute, en définitive, grâce à une propriété "humorale" que les Orchidées peuvent imposer à leurs hôtes un mode de végétation capable de ralentir et de régler leur envahissement.

We are thus practically brought back to socio-physiological causes, in particular to feeding and what is involved in biological and related physiological activities. For it is clear that " physico-chemical reasons," " composition of sap," " humoral properties," suggest, above all, Food ; and when we find the higher plant regulating or slackening the activities of the associated fungus, this suggests the exercise and also the imposition of symbiotic restraint, the operation of symbiotic momenta.

As though to emphasise his chief weakness, which consists in the fact of having overlooked the significance of Norm-Symbiosis, Prof. Bernard remarks on the last page of the "mémoire," that :

Les conditions qui peuvent se substituer à la symbiose, comme par exemple un degré relativement élevé de concentration du milieu de culture, sont indépendantes de la plante, extérieures à elle pour ainsi dire et peu capables de se modifier par son action.

As though the " autonomous " life of a plant were normally one undetermined by Symbiosis !—were a life of isolation, of helplessness and of accidents ! No wonder such narrowness of view leads to a misapprehension of the entire relation between fungus and higher plant, and to a fatal misconstruction of the evidence afforded by research, however painstaking. Contrary to Prof. Bernard's opinion, it is to a large extent in the power of the autonomous plant to find good equivalents for fungal help or

for highly concentrated solutions, and to determine the composition of its protoplasm in a favourable sense by means other than those suggested by him, *e.g.*, by creating the conditions auspicious to the incidence, and the increasing value of, cross-fertilisation and at the same time to the distribution of seeds by animal-agency. And the secret to the consummation is this : service. To have failed in fundamental service is, in my opinion, the root-defect of orchidean life.‡

From considerations to be drawn from Darwin's *Fertilisation of Orchids*, we may now infer strong confirmation of the view that orchidean Norm-Symbiosis is in decay, owing largely to the distractions and exactions of Luxury-Symbiosis with fungi. It is as though the propitiating of the fungi by the orchids involved physiological expenditure too great to allow of adequate margins for successful Symbiosis with superior helpers, namely, the insects.

Symbiosis, of course, was unknown when Darwin wrote ; but having been blamed for propounding the doctrine that the higher organic beings require an occasional cross with another individual, without giving ample facts, he wished to show in this volume that he had not spoken without having gone into details.

Direct proofs of his contention were given in his *The Effects of Cross and Self-Fertilisation in the Vegetable Kingdom* (the cases being for the most part, if not all, drawn from dicotyledonous plants). Here, in the case of the (monocotyledonous) orchids, Darwin confines himself in the main to pointing out the frequency and perfection of the contrivance for cross-fertilisation, which would seem to render it highly probable that cross-fertilisation was the pristine condition of life amongst the ancestors of the orchids ; and in view of these facts, Darwin thinks it again demonstrated that there is something injurious in self-fertilisation, and he concludes that " it is hardly an exaggeration to say that Nature tells us, in the most emphatic manner, that she abhors perpetual self-fertilisation."

But, although the apparatus for cross-fertilisation persist, the institution itself may have lost much of its former virtue. The value of the respective biological interaction depends largely upon the quality of the surplus products which the plant has to offer. In the case of the orchids, Darwin himself provides evidence to show that plants differ widely in the quality

of the "attractions" they offer, so much so as to cause some plants to be neglected or avoided by the better classes of insects, which are attracted, we may assume, by superior offerings elsewhere. And he shows further that sometimes the contrivances in one and the same flower are contradictory, *i.e.*, they are partly meant for cross- and partly for self-fertilisation; this, in my opinion, pointing to a deep-seated socio-physiological conflict and a deterioration, whilst, according to Darwin, it renders such cases "perplexing in an unparalleled degree."

Starting with the *Ophreæ*, he tells us that "*Neotinea (Orchis) intacta*, a very rare British plant, produces seeds without the aid of insects, the plant apparently being self-fertilising," and *pro tanto*, so we must conclude, according to his own aphorism, the poorer in vitality and survival-capacity.

Here then we have evidence of sociological, combined with physiological, retrogression owing to failure of Norm-Symbiosis. Nor does the substitution of fungal Symbiosis offer adequate compensation for the losses so entailed.

Again, *Orchis fusca* offers a case of imperfect fertilisation, and Darwin suspects that the species is so rare in Britain "from not being sufficiently attractive to insects, and to its not producing a sufficiency of seed," which again shows socio-physiological inferiority, and may serve as an illustration of the truth that you cannot serve two masters at the same time, and, further, that it is better for an organism to comply with high rather than with low sociological conditions.

Orchis latifolia and *Morio* seem to provide a case of "sham-nectar-producers" —termed "Scheinsaftblumen" by the excellent Sprengel, to whom Darwin here again pays a high tribute—a "gigantic imposture," if true, as Darwin says. Such "sham-nectaries," however, he thinks to exist more probably in the case of *Ophrys muscifera*, the Fly Orchis, with its inconspicuous and scentless flowers, all of which, again, points to a decay of Norm-Symbiosis owing to a deficiency of service.

Again, *Orchis pyramidalis* often produces monstrous flowers without a nectary, or with a short and imperfect one, and the better class of insects, it appears, show little *gusto* for visiting such "acromegalic" flowers. As regards *Orchis pyramidalis* and the allied *O. maculata*, Darwin further states: "We may therefore safely conclude that the nectaries of the above-named orchids neither in this country nor in Germany ever contain nectar."

Evidently, Luxury-Symbiosis has greatly detracted from the physiology proper to Norm-Symbiosis.

Darwin apparently apprehended some mystery. His observations showed that out of 207 flowers examined, not half had been visited by insects and of the 88 flowers visited 31 had only one pollinium removed. This is his comment :

As the visits of insects are indispensable for the fertilisation of this Orchid, it is surprising (as in the case of *Orchis fusca*) that the flowers have not been rendered more attractive to insects. The number of seed-capsules produced is proportionably even less than the number of flowers visited by insects. The year 1861 was extraordinarily favourable to this species in this part of Kent, and I never saw such numbers in flower; accordingly I marked eleven plants, which bore forty-nine flowers, but these produced only seven capsules. Two of the plants each bore two capsules, and three other plants each bore one, so that no less than six plants did not produce a single capsule! What are we to conclude from these facts? Are the conditions of life unfavourable to this species, though during the year just alluded to it was so numerous in some places as to deserve to be called quite common? Could the plant nourish more seed; and would it be of any advantage to it to produce more seed? Why does it produce so many flowers, if it already produces a sufficiency of seeds? Something seems to be out of order in its mechanism or in its conditions.

"Want of attractiveness to insects," though rather puzzling, was as far as Darwin could go in surmising the cause of the backwardness of this species. Further explanation had to wait for the elucidation of the socio-physiological laws determining the depauperisation of plants. Darwin is astonished at the fact that the flowers have not "been rendered" (by whom or what?) more attractive to insects. He searches for some expedient usefulness. Apparently we are not to blame Nature, nor "Natural Selection," nor the Omnipotent Creator (expressly dismissed on p. 245) for the plight of the plant. It seems plain, therefore, that we can only reprobate the plant itself for failing in its duties as a responsible bio-economic agent. If the plant be "out of condition," this is because for some reason or other its metabolism is not what it should be. If the plant exert but diminished "attraction," such predicament, here as elsewhere, is due to a loss of viability and of integrity; and it is of vital importance to discover the respective sequence of cause and effect.

Like the Fly Orchis, the Spider Orchis is but little visited by insects in England, and in Italy even less so. *Ophrys apifera*, the Bee Ophrys, contrary to what is the rule amongst orchids generally, is even "excellently constructed for fertilising itself"

—a self-sufficiency which, though not prejudicial to numbers, is yet detrimental to the ultimate well-being of the species. For, as already mentioned, the plant presents a dimorphism—an antagonism between a condition of cross-fertilisation and one of self-fertilisation, so much so as to cause Darwin to exclaim that the case is “perplexing in an unparalleled degree.”

And perplexing the case of the Fly Orchis certainly is, unless we attribute the dualism of contrivances to a double state of biological relation—one a state of lingering Norm-Symbiosis, and another, conflicting with and detracting from it: a state of Luxury-Symbiosis; the dualism in the last analysis presenting an antithesis between a cross-feeding and an in-feeding state.

By way of contrast with the above cases, we might mention an orchid emitting “a strong honey-like odour, such as *Herminium monorchis*, the Musk Orchis; and here we find that although the flowers are small and inconspicuous, yet “they seem highly attractive to insects”—*de toute taille bon chien*.

Darwin's son, George, brought home no less than twenty-seven specimens of minute insects with pollinia attached to them. These insects belong to Hymenoptera, Diptera and Coleoptera.

So with *Gymnadenia Conopsea*:

the flowers smell sweet, and the abundant nectar always contained in their nectaries seems highly attractive to Lepidoptera, for the pollinia are soon and effectually removed.

We may take it that these sweet-scented orchids are little given to in-feeding, and that, hence, they are not extremely determined by the fungi.

If we come to the Arethuseæ, an interesting example is presented by *Cephalanthera Grandiflora*, which, as Darwin says, is like a degraded Epipactis, a member of the Neotteeæ. Darwin never found a trace of nectar within the cup of the labellum. Yet, as there is evidence of insect visits, Darwin's search brought to light the fact that there are insects which gnaw the ridges of the flowers, and he says:

The ridges had a taste like that of the labellum of certain Vandeæ in which tribe this part of the flower is often gnawed by insects. *Cephalanthera* is the only British Orchid, as far as I have observed, which attracts insects, by thus offering to them solid food.

Here, as in the case of the Bee Orchis, we have self-fertilisation. It seems, therefore, that insects of some kind visit the flowers, disturb the pollen, and leave masses of it on the stigmas

—a case of imperfect self-fertilisation. Apparently we have here a low form of biological intercourse, the insects being very insignificant as “partners.” Quite likely, too, the carbo-hydrates offered by these orchids are of little value, and the fungi have already had the lion’s share of what production there is. The poverty of solid food production on the part of orchids generally, seems a noteworthy fact, testifying to the inferior value of Norm-Symbiosis in the case of these plants.

Another member of the Arethuseæ, *Pterostylis trullifolia* also fails to secrete nectar. The flowers seem to be frequented exclusively by Diptera (flies)—again a low intercourse—“but,” says Darwin, “what attraction they present is not known, as they do not secrete nectar.”

Of *Vanilla aromatica*, the flowers of which are adapted to be fertilised by insects, Darwin says that when this plant is cultivated in foreign countries, for instance in Bourbon, Tahiti, and the East Indies, it fails to produce its aromatic pods unless artificially fertilised. According to him, this shows that

some insect in its American home is specially adapted for the work; and that the insects of the above-named tropical regions, where the *Vanilla* flourishes, either do not visit the flowers, though they secrete an abundance of nectar, or do not visit them in the proper manner.

But if the production of the aroma, and what this entails in physiological and biological advantages to both producer and consumer, is thus evidently closely associated with fertilisation—best performed by animal agency—this shows that productiveness generally follows in the wake of Norm-Symbiosis. Anything which detracts from such Symbiosis, must lead to inferior adaptations, to weakness, and to retrogression.

Again, in another case, Darwin records that the nectar of a Guatemala Orchid seemed too powerful for our British bee, for it stretched out its legs and lay for a time as if dead on the labellum, but afterwards recovered.

We may conclude that it is not the production of nectar *per se* which determines the value of Norm-Symbiosis, but that it is the physiological condition, the origin, nurture, etc., of the nectar which are the determining factors. And if this be so, it follows that in carbo-hydrate as in scent production, any interfering secondary cause, such as Luxury-Symbiosis, may easily result in the deterioration of the product originally adequate enough to Norm-Symbiosis.

Very remarkable evidence enlightening us concerning the state of Norm-Symbiosis in their case, namely that of the *Neottæ*, is provided by Darwin, first with regard to *Epipactis palustris*. Apart from several small flies (*Coelopa frigida*), and three or four distinct kinds of Hymenoptera (one of small size being *Crabro brevis*) visiting these orchids, there is a large fly, *Sarcophaga carnosa*, haunting them, a fact which Darwin finds the more remarkable as the *Sarcophaga* frequents decaying animal matter and the *Coelopa* haunts seaweed, occasionally settling on flowers. We are further told :

The *Crabro* also, as I hear from Mr. F. Smith, collects small beetles (*Halticæ*) for provisioning its nest. It is equally remarkable, seeing how many kinds of insects visit this *Epipactis*, that although my son watched hundreds of plants for some hours on three occasions not a single humble-bee alighted on a flower, though many were flying about.

The *Sarcophaga* had already been mentioned by Darwin in connection with the Fly Orchis, the scentless and inconspicuous flowers of which, it will be remembered, he suspected of possessing "sham-nectaries." To be seen in such low company as these flies does not redound to the credit of the orchids. I should be inclined to consider the respective "attractions" as belonging to the pathological order, closely akin to those by which a beast of prey becomes aware, even at a considerable distance, of the presence of diseased individuals. And if these orchids are so poorly connected in the insect world, this, in my opinion, is for the reason that they have become as in-feeders, too indolent for, and too ineffective in, Norm-Symbiosis.

Two other *Epipactis*, *E. latifolia* and *E. purpurata*, are frequented by "swarms of wasps"—the highwaymen amongst Hymenoptera—and Darwin states :

It is very remarkable that the sweet nectar of this *Epipactis* should not be attractive to any kind of bee. If wasps were to become extinct in any district, so probably would the *Epipactis latifolia*.

Again it must be pointed out that although the nectar be "sweet," it may not be of such a composition as to suit it for the purposes of advanced Norm-Symbiosis. It may be an article "de luxe" rather than a food ; it may be fit for scavengers and "mixed" feeders rather than for symbiotic cross-feeders. We have not yet learned to discriminate with regard to Nature's finer forces as purveyed by food ; but during the next 500 years we may learn a little more respecting these important matters.

Epipactis viridi-flora, according to Darwin, is regularly self-fertilised. *Spiranthes australis*, an inhabitant of Australia, fertilises itself as regularly as does *Ophrys apifera*. *Listera ovata*, the Tway-blade, according to Darwin, one of the most remarkable in the whole order (Neotteæ), is visited by small Hymenopterous insects and also by Diptera. Darwin's son was "struck with the number of spider-webs spread over these plants, as if the spiders were aware how attractive the *Listera* was to insects." As regards this latter observation, we have here indeed, I believe, evidence of a vicious circle of morbid "awareness"—a perversion of symbiotic "awareness." And the basis of this low kind of "awareness" is this: the common desire for in-feeding. Birds of a feather flock together.

Of the "unnatural sickly looking" *Neottia-nidus-avis*, Darwin merely remarks that:

the labellum secretes plenty of nectar, which I mention merely as a caution, because during one cold and wet season I looked several times and could not see a drop, and was perplexed at the apparent absence of any attraction for insects; nevertheless, had I looked more perseveringly, perhaps I should have found some.

Probably Diptera are instrumental in removing the pollinia. However, "a good deal of friable pollen is often left behind in the anther-cells and is apparently wasted." "The spreading of the pollen seems to be in part caused by the presence of Thrips, many of which minute insects were crawling about the flowers, dusted all over with pollen."

The minute crawling insects assure "self-fertilisation," "should larger insects fail to visit the flowers"—and apparently these do fail. *Thelymitra carnea*, another member of the Neotteæ "invariably fertilises itself by means of the incoherent pollen falling on the stigma"; the flowers "seem tending towards a cleistogene condition."

Amongst *Cattleya* we are told that self-fertilisation is pretty frequent, whilst others are imperfectly fertilised by insects. A curious instance of a "nectar-de-luxe" is furnished by Darwin in the case of *Coryanthes*, belonging to the "immense tribe of the Vandææ, which includes many of the most magnificent productions of our hothouses."

What is secreted is a limpid fluid "so slightly sweet that it does not deserve to be called nectar, though evidently of the same nature; nor does it serve to attract insects," and we are provided

with an account by Dr. Cruger, of what may happen in the case of the visiting bees which are "seen in great numbers disputing with each other for a place on the edge of the hypochil (*i.e.*, the basal part of the labellum). Partly by this contest, partly perhaps intoxicated by the matter they are indulging in, they tumble down into the 'bucket,' half-full of a fluid secreted by organs situated at the base of the column."

To cut the story short, the humble-bee, in forcing its way out of its involuntary bath, will have the gland of the pollen-mass glued to its back and it will eventually fertilise the same or some other flower. One cannot but think that the deception is overdone, the plant working on the indulgence rather than upon the healthy instinct of the insects. The necessity of having to provide the "bath" recalls the case of *Drosera*, inasmuch as in either case a great deal of fluid is required for the biological operations of the plant. In either case, we may say, the excess of water reacts injuriously upon the protoplasm and is certain in the end to leave both plant and associated insects the poorer for the trickery. The *Vandae* have avoided self-fertilisation; but they have had recourse to forms of Norm-Symbiosis which are of a dubious character. Here again we may infer that fungal Symbiosis has been a disturbing rather than a helpful factor.

Darwin perceived that the production of nectar was of transcendent importance; but he still underestimated the full socio-physiological importance of the matter. Had he started from the proposition that it is the highest purpose of the plant to be *widely* useful, instead of embracing the narrower (Müllerian) view that "the final end of the whole flower, with all its parts, is the production of seed," this would have led him to a better appreciation of the fundamental economy of Nature than is implied by the teaching of "Natural Selection."

In the work under review, he again devotes a special chapter to the "Secretion of Nectar," and states:

Although the secretion of nectar is of the highest importance to Orchids by attracting insects, which are indispensable for the fertilisation of most of the species, yet good reasons can be assigned for the belief that nectar was aboriginally an excretion for the sake of getting rid of superfluous matter during the chemical changes which go on in the tissues of plants, especially whilst the sun shines.

Here again we have a case of Bio-Chemistry merging itself into Bio-Economics. What matters most is that the respective

metabolism furnishes a bio-economically desirable surplus product, *i.e.*, one capable, *inter alia*, of stimulating progressive evolution amongst animals. Whether or no the vegetable metabolism is to be fruitful in bio-economic good effects, depends largely upon the feeding habits and the connected "industries" of the plants. Unless these are of a socio-physiologically high order, there can be no valuable surpluses of metabolism.

For in Nature, as in human life, all real values are based upon labour; and, here as there, it is all-essential that the organism earn its living and discharge its obligations by adequate service. It is considerations such as these that have been far too long disregarded in biological philosophy.

Darwin states :

It is in perfect accordance with the scheme of nature, as worked out by natural selection, that matter excreted to free the system from superfluous or injurious substances should be utilised for highly useful purposes.

I should say, however, that the usefulness here entailed is one in accordance with a scheme of definite service between organism and organism, of "Symbiosis: Organic and Social," of which scheme, in the words of Prof. Patrick Geddes, neither Economist nor Naturalist has hitherto been able to provide an outline.

Darwin continues thus :

To give an example in strong contrast with our present subject, the larvæ of certain beetles (*Cassidæ*, etc.), use their own excrement to make an umbrella-like protection for their tender bodies.

Certainly these larvæ have a curious way of providing for their swaddling clothes; their case, however, furnishes but poor illustration of the contrast which ought here to have been shown—though this would have amounted to a relegation of "Natural Selection" to the lumber-room of exploded scientific theories. The contrast that should have been shown is that between a healthy and a morbid circle of affinities, based upon a good and a bad metabolism respectively. To provide a few examples of a morbid circle of affinities: there are a number of relations between animals of different species, coming under the head of "Commensalism," which are apt to degenerate into a kind of social disease comparable to that of alcoholism amongst men. The ants, for example, may become so "drunk" with the excretions of some of their commensals and so intent upon the gratification, that they neglect their social duties, and even suffer their own

offspring to be preyed upon and decimated by their "domesticated" allies. The disease has also been described under the name of "Symphily."

Another vicious circle produced by similar indulgence is presented by the following example: the highly predaceous Aphides, preying upon our pampered garden productions, excrete a sweet substance upon the leaves of the plants, which substance is very acceptable to certain fungi, enabling them to multiply inordinately and thus to become a further pest upon these plants. One parasite thus frequently abets another, the inverse order of utility being in fact presented to what biological use and biological relation should be. Although there be thus a utilisation of metabolic surpluses, there is often nothing to show that they serve some really "highly useful purpose." On the contrary, they serve a bad purpose, and it is fatal not to make the respective distinctions. It is equally important to recognise that the disease began with a setting aside of the conditions of moderation as required by Symbiosis.

The same criticism applies to Darwin's further remarks with regard to the profusion of seeds amongst orchids. He fully admits that such profusion is not anything to boast of:

for the production of an almost infinite number of seeds or eggs is undoubtedly a sign of lowness of organisation. That a plant, not being an annual, should escape extinction, chiefly by the production of a vast number of seeds or seedlings, shows a poverty of contrivance, or a want of some fitting protection against other dangers.

The orchids, then, we must assume, rank both high and low; the former in view of their wonderful cross-fertilising contrivances, and the latter because of their redundant multiplications. Which is it to be: high or low rank? The discrepancy disappears if we judge both multiplication and cross-fertilisation by bio-economic standards.

Darwin had already mentioned (p. 225) that with regard to the orchids we are in complete ignorance of the requirements and conditions of life, and in his concluding remarks he similarly states:

What checks the unlimited multiplication of the Orchideæ throughout the world is not known.—The frequency with which throughout the world members of various Orchideous tribes fail to have their flowers fertilised, though these are excellently constructed for cross-fertilisation, is a remarkable fact.

When we read of a capsule of a *Maxillaria* containing 1,756,440

seeds, and when we consider the manifold power of contrivance, in Darwin's words: "their prodigality of resources," they being "more highly endowed in their mechanism for cross-fertilisation, than are most other plants"—we can only conclude that there exists amongst orchids a lack of really wide bio-economic usefulness of life.

Neither can Darwin's own attempt at explaining the discrepancy in the least deter us from taking this bio-economic view of the matter. He says:

Profuse expenditure is nothing unusual under nature, as we see with the pollen of wind-fertilised plants, and in the multitude of seeds and seedlings produced by most plants in comparison with the few that reach maturity. In other cases the paucity of the flowers that are impregnated may be due to the proper insects having become rare under the incessant changes to which the world is subject; or to other plants which are more highly attractive to the proper insects having increased in numbers.

But we have learnt that such profuse expenditure, at least in the case of certain wind-fertilised weeds, is apt to convey disease to animals and men, and we shall not be far wrong in concluding that the profuse expenditure is in itself pathological.

Again, the rarity of "proper" insects will, no doubt, in most cases be due to failure of bio-economic service on the part of the plant, the more attractive plants being precisely those which have remained faithful on the path of Symbiogenesis instead of drifting, as the neglected species have done, into Pathogenesis. We have no further use, therefore, for the term "favoured in some other way," and for all similar "Selection" jargon, which has too long called away the attention from the most vital lessons to be gleaned from the study of evolution.

In bidding good-bye to the subject of Symbiosis and Disease, I have only one more word to add: some of my critics have gravely taken me to task for seeing morality in Nature. When I say that a plant's behaviour is (biologically speaking) "bad," I do not mean to say that it is to be blamed in the sense in which one would reprobate a European for serious moral transgression. I would not blame a cannibal in this sense. Neither do I blame my critics for their "non-moral" views. But although I would not blame a cannibal for eating his wife, as I would a European under similar circumstances, yet I cannot but think that there is *some* blame in the cannibal's case, and that, similarly, there is *some* blame in the case of bio-moral transgression.

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